| AD NUMBER |
|---|
| AD019990 |
| **CLASSIFICATION CHANGES** |
| TO: unclassified |
| FROM: confidential |
| **LIMITATION CHANGES** |
| TO: Approved for public release, distribution unlimited |
| FROM: Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; SEP 1953. Other requests shall be referred to Office of the Chief of Engineers [Army], Washington, DC. |
| **AUTHORITY** |
| USAEWES ltr, 28 Mar 1979; USAEWES ltr, 28 Mar 1979 |

AFSWP-137

CONFIDENTIAL
Security Information

CORPS OF ENGINEERS, U. S. ARMY



# EFFECTS OF EXPLOSIONS IN SHALLOW WATER

REPORT NO. 8

## CRATERING EFFECTS IN CLAY SOILS FOR SCALED WATER DEPTHS OF 30, 60, 100, AND 200 FT.



CONDUCTED FOR

ARMED FORCES SPECIAL WEAPONS PROJECT
DEPARTMENT OF DEFENSE

AND

THE CHIEF OF ENGINEERS
DEPARTMENT OF THE ARMY

BY THE

WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

SEPTEMBER 1953

CONFIDENTIAL
Security Information

AFSWP-137

CORPS OF ENGINEERS, U. S. ARMY

# EFFECTS OF EXPLOSIONS IN SHALLOW WATER

## REPORT NO. 8

## CRATERING EFFECTS IN CLAY SOILS FOR SCALED WATER DEPTHS OF 30, 60, 100, AND 200 FT.

CONDUCTED FOR

ARMED FORCES SPECIAL WEAPONS PROJECT
DEPARTMENT OF DEFENSE

AND

THE CHIEF OF ENGINEERS
DEPARTMENT OF THE ARMY

BY THE

WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

ARMY-MRC VICKSBURG, MISS.

SEPTEMBER 1953

# PREFACE

This is the eighth report in a series to be published on the study of "Effects of Explosions in Shallow Water," being conducted for the Armed Forces Special Weapons Project, Department of Defense, and the Corps of Engineers, Department of the Army, by the Waterways Experiment Station. The study is concerned with scaled explosions of 20 kilotons of TNT in water depths of 30, 60, 100, and 200 ft. Reports are published intermittently to describe a completed phase or series of tests. At the end of the study, a final report will be prepared which will attempt to correlate and summarize the results of the entire testing program.

This report describes the results of field tests conducted in isolated areas along the Mississippi River to determine the cratering effects in various types of clay soils for scaled water depths of 30, 60, 100, and 200 ft.

A list of reports in preparation or published to date is printed on the inside of the front cover for the information of the reader.

Symbols and the less familiar abbreviations used throughout this report are defined on page 15.

EFFECTS OF EXPLOSIONS IN SHALLOW WATER

REPORT NO. 8

# Cratering Effects in Clay Soils For Scaled Water Depths of 30, 60, 100, and 200 ft

## Introduction

1. Reported herein are the results of a series of small-scale tests to determine the cratering effects in various types of clay soils caused by an explosion of 20,000 tons of TNT in water depths of 30, 60, 100, and 200 ft. The tests were conducted in three isolated areas along the Mississippi River.

## Description of Test Sites

2. Three sites were selected which would provide undisturbed bottom materials of varying characteristics for the cratering tests. Throughout this report the sites will be referred to as Diamond Point, Delta Point, and Sorrento. The Diamond Point and Delta Point sites were located on the west bank of the Mississippi River, approximately 10 miles and 3 miles, respectively, south of Vicksburg, Mississippi. The third site was located on the east side of the Mississippi River, about 20 miles southeast of Baton Rouge, near Sorrento, Louisiana. The sites were selected after soil tests were made to determine the characteristics of the clays found at each location. In preparation for the tests the top 2 to 4 ft of earth was excavated to remove weathered layers of clay or in some

cases an overburden of loose silt. The excavation also provided a basin which was flooded to the proper depths for the test shots. The test basins were 30 to 60 ft wide and 80 to 100 ft long. Water for flooding the basins was supplied from nearby lakes, or from the river, by means of portable, gasoline-motor-driven pumps.

## Soil Characteristics at Test Sites

### Diamond Point

3. The bluish-gray clay, characteristic of the Diamond Point area, is of backswamp origin and is classified as a stiff clay. The shear strength, determined by unconfined compression tests on undisturbed samples, varied from 0.44 to 0.74 ton per sq ft with an average of 0.59 ton per sq ft. The average moisture content* as determined from borings 10 to 12 ft deep was 37 per cent, and the average plasticity index was 52. The clay was fairly brittle, since all samples failed at strains of less than 5 per cent.

### Delta Point

4. The Delta Point clay is firm, brown to gray in color, and made up of recent river-channel filling. The shear strength to a depth of 8 ft varied from 0.19 to 0.37 ton per sq ft, the average being 0.27 ton per sq ft. The average moisture content was

---

$$\text{*Moisture content} = \frac{\text{wet weight of sample} - \text{dry weight of sample}}{\text{dry weight of sample}} \times 100$$

46 per cent down to depths of 10 ft and the plasticity index was 55. With one exception, all samples failed at strains less than 5 per cent, thus indicating a fairly brittle material.

**Sorrento**

5. This Pleistocene clay is brown to a depth of about 4 ft and tan and gray to a depth of 10 ft. The consistency indicated by the unconfined compression tests varied from firm to hard. The shear strength averaged 0.36 ton per sq ft to a depth of 3 ft, 0.84 ton per sq ft between 3 and 7 ft, 0.49 ton per sq ft between 7 and 9 ft, and 0.26 ton per sq ft for one sample at a depth of 9.3 ft. The moisture content of the clay was somewhat variable, although the average moisture content was 24 per cent. The average plasticity index was 27. The strain measurements indicated that the Sorrento clay was more elastic than either the Diamond Point or Delta Point clays in that the higher strength samples failed at strains up to 19 per cent.

6. Results of soils analysis of the various materials are summarized in table A. Two additional type soils, Dahlgren clay and loess, have been added for purposes of comparison. Since the top 2 to 4 ft of clay was removed at each site prior to testing, and most of the crater depths extended no more than 7 ft below the original ground surface, the tabular data, except those for Dahlgren, are average values of the various characteristics for undisturbed samples taken at depths between 3 and 7 ft below original ground surface. The tabulated values therefore may not

## TABLE A

### Soils Characteristics

| Soil | Dry Density lb/cu ft | Moisture Content (%) | Liquid Limit (%) | Plastic Limit (%) | Plasticity Index | Cohesive Strength (Tons/sq ft) |
|---|---|---|---|---|---|---|
| Diamond Pt. clay | 82 | 37 | 81 | 29 | 52 | 0.60 |
| Delta Pt. clay | 76 | 46 | 90 | 35 | 55 | 0.22 |
| Sorrento clay | 109 | 25 | 46 | 19 | 27 | 0.34 |
| Dahlgren clay | 49 | 89 | 105 | 31 | 74 | 0.05 |
| Loess | 95 | 24 | 40 | 18 | 22 | 0.35 |

agree exactly with those stated in paragraphs 3-5, since the latter include data obtained from samples taken above and below the 3- to 7-ft range. For Dahlgren clay it was not possible to obtain undisturbed samples, therefore the analysis was made from samples* of the crater-lip material which extended above the water surface after the explosion. For this reason the moisture content as tabulated for Dahlgren clay may be in excess of that of an undisturbed specimen.

---

*Samples were furnished gratuitously to the Waterways Experiment Station by Mr. G. A. Young, NOL Project 152, Indian Head, Md.

while the dry density may be slightly lower. It is believed that the cohesive strength of the Dahlgren clay was materially higher prior to the blast than that recorded in table A. The reduction is attributed to the breakdown in cohesive strength caused by the explosion.

## Similitude Considerations

7. The principle of similarity generally accepted for experiments with explosive charges states that if the linear size of a charge is changed by some factor K, the pressure condition will be unchanged if the scales of distance and time are changed by the same factor. That is, once the pressure condition and the magnitudes of other physical phenomena associated with an explosion are known for a specific charge weight, they can be written for another explosion as functions of time and distance by scaling all times and distances in accordance with the ratio of the linear sizes of the two charges. The cube root of the charge weight was used as a convenient measurement of linear size.

8. The water depths used in the tests were determined, therefore, by the ratio $D/W^{1/3}$ which has numerical values of 0.088, 0.175, 0.292, and 0.585, respectively, for water depths (D) of 30, 60, 100, and 200 ft, and a charge weight (W) of 20,000 tons. Actual water depths for test charge weights of 4 and 32 lb were as listed below:

| Full-Scale Water Depth D (ft) | $D/W^{1/3}$ | Actual Water Depths (ft) | |
|---|---|---|---|
| | | W = 4 lb | W = 32 lb |
| 30 | 0.088 | 0.14 | 0.28 |
| 60 | 0.175 | 0.28 | 0.56 |
| 100 | 0.292 | 0.47 | 0.93 |
| 200 | 0.585 | 0.93 | 1.85 |

## Test Conditions and Procedures

9. The study of explosions in shallow water initially involved the determination of effects of exploding 20,000 tons of TNT in water depths of 30 and 200 ft on (a) cratering in various soils, (b) air-blast, (c) shock-waves in water and earth, and (d) surface water waves. During a conference held in February 1952, attended by representatives of the Armed Forces Special Weapons Project, the Chief of Engineers, and the Waterways Experiment Station, it was concluded that tests in intermediate water depths would be desirable, particularly with reference to cratering effects and water waves. It also was concluded that a study should be made of United States harbors to determine a representative bottom material for crater-test purposes. As the result of the conference and the subsequent study* a bottom material of clay and intermediate water depths of 60 and 100 ft were selected for the additional tests.

---

*"Soil Conditions Beneath Coastal Harbors - United States," Waterways Experiment Station, July 1952 (AFSWP-130).

10. Results of tests concerned with cratering effects in sand and loess soil, and measurements of surface waves and air blast for scaled water depths of 30, 60, 100, and 200 ft are contained in Reports Nos. 1-7. The tests reported upon herein were concerned only with cratering effects in clay soils for the four scaled water depths.

11. The tests were conducted on undisturbed clays to avoid the possibility of changing the shearing properties of the soil by remolding the bottom after each shot. As mentioned in paragraph 2, the tests were carried out at separate locations to obtain cratering effects in clays of different consistencies and shearing strengths.

12. Since previous tests with other type soils had indicated that charges detonated at or below the bottom were most effective for cratering, the study of cratering effects in clay was limited to two charge positions, bottom and a scaled 90 ft below bottom. However, to provide data for correlation with previous tests in loess soil, a series of shots was fired at mid-depth in the scaled 200-ft water depth at the Diamond Point test site. The Diamond Point site was the only location where tests were carried out in all four of the scaled water depths. Tests at Delta Point and Sorrento were limited to the 30- and 200-ft scaled depths. Charge weights of 4 and 32 lbs were selected for the tests.

13. The charges were made up with standard Corps of Engineers 1-lb TNT demolition blocks arranged to maintain geometric similarity

of charge dimensions as described in previous reports. The charge center of gravity, with the long side in the vertical position, was used as the reference for charge position. Two identical charges were fired for each test condition to enhance the value of the results.

14. Testing procedures for crater measurements were generally similar to those described in Reports Nos. 5 and 6. Locations where the charges were to be detonated were carefully prepared by stripping off any layer of eroded clay or silt down to firm, consistent clay. The excavated area was then flooded to the proper depth, and the charge placed and detonated. The resulting crater was sounded by means of an aluminum rail supported horizontally and centered over ground zero, which provided both horizontal and vertical control for crater measurements. At least two profiles through representative cross sections of each crater were obtained in this manner.

## Test Results

### Test data

15. The results of cratering tests in clay soils for scaled water depths of 30, 60, 100, and 200 ft, using 4- and 32-lb charges, are summarized in tables 1-6. Complete profiles were taken through two representative sections of each crater and the data were plotted as an average half-crater profile. The crater dimensions listed in the tabulations were obtained from these plots and refer exclusively to the apparent crater, since it was impossible to obtain true-crater

measurements under submerged conditions. Reduced crater dimensions, defined as the dimension divided by the cube root of the charge weight, are listed also in the tables.

16. Tables 7-9 present for comparison the theoretical and experimental values of K and n*. Theoretical values, based on the cube-root-of-charge-weight law, were obtained by averaging the values for both charge weights of the reduced crater dimensions listed in tables 1-6. Experimental values were determined by algebraic computations based on the actual crater dimensions shown in the tables. Although a number of the experimental values of n are at variance with the cube-root law, the results must be considered from the view that only two charge weights were used and tests were repeated only one time.

17. Photographs 1-7 are views of typical craters resulting from a representative number of test conditions. The large clods of bottom material lying in and around the craters made the sounding quite difficult, particularly in the lip areas.

18. Plates 1-6, 28-29, 37-38, and 46-51 present plots of the average half-crater profiles for each test condition. Each plotted point is the average of four independent soundings taken at equal radial distances from ground zero. Listed on each plate are the average values of the six parameters of interest in cratering:

---

*Where K and n are elements of the empirical equation, $P = KW^n$.

depth, width, lip height, lip width, cross-sectional area, and volume. The plates present the results obtained with charges positioned at a scaled depth of 90 ft below bottom and at the bottom, except for tests in the 200-ft scaled depth at the Delta Point site where only the bottom-detonated charges were used. Tests in the 30-ft scaled water depth at this location yielded results quite similar to previous tests at Diamond Point (compare plates 7 and 8), therefore tests at Delta Point in the 200-ft depth were reduced to one charge position. In addition to the charges positioned at and below bottom, the mid-depth position was tested in the 200-ft scaled depth at the Diamond Point site to provide additional reference points for correlating with the results obtained previously in sand and loess.

19. Plates 7-9, 30, 39, and 52-54 present the variation of crater depth with charge weight for scaled water depths of 30, 60, 100, and 200 ft, respectively. Since only two charge weights were used, and past experience has indicated cratering to be a function of approximately the cube-root law for these charge positions, lines were drawn through the computed intercept on a one-third slope and the equation was determined for each. A like procedure was followed in developing other log-log plots for crater width (plates 10-12, 31, 40, and 55-57), lip height (plates 13-15, 32, 41, and 58-60), cross-sectional area (plates 16-18, 33, 42, and 61-63), and volume (plates 19-21, 34, 43, and 64-66).

20. Dimensionless plots of the average half-crater profiles for each of the scaled water depths and charge positions are presented on plates 22-27, 35-36, 44-45, and 67-72. In the upper plot of each plate, X/r is plotted against Y/d. The ordinate is the ratio of crater depth at any point to the crater depth at ground zero, and the abscissa is the ratio of radial distance from the charge to the crater radius. Also shown in dimensionless form are the plots of $X/W^{1/3}$ vs $Y/W^{1/3}$, where X is the radial distance from the charge, Y is the crater depth at the radial distance X, and $W^{1/3}$ is the cube root of the charge weight.

## Discussion of Results

21. The variation of crater dimensions with charge weight as shown on the log-log plots indicates fair agreement with the cube-root scaling principle in that the plotted points, with the exception of lip-height measurements in the Sorrento clay (plates 15 and 60), fall close to the straight lines which were fitted to the data on the basis of the cube-root law. The plotted points on plates 15 and 60 indicate that lip height varied approximately as $W^{0.75}$ in the 30-ft scaled depth, and as $W^{0.60}$ in the 200-ft scaled depth. However, in view of results obtained at the other clay sites (plates 13-14, and 58-59), as well as those in loess (Report No. 4), the plots on plates 15 and 60 represent what is believed to be the best compromise for the data obtained in Sorrento clay.

22. Significant crater lips were formed in each scaled water depth for the charge positions tested. The dimensionless plots (plates 22-27, 35-36, and 44) show that the values of $Y/W^{1/3}$ at the point of maximum lip height are somewhat greater than the corresponding values of $D/W^{1/3}$ for the scaled 30-, 60-, and 100-ft water depths, indicating that the crater lip extended above the water surface and, in the case of a prototype weapon detonated at or below the bottom in a harbor, may create a navigational hazard. Since the bottom material deposited in the lip area was composed primarily of large clods, the lips formed were not sufficiently uniform in height about the periphery of the crater to cause the formation of a dry crater. In the 200-ft scaled water depth (plates 67-72) values of $Y/W^{1/3}$ at the point of maximum lip height are no more than one-half the value of reduced water depth ($D/W^{1/3} = 0.585$), thus indicating that crater lips would not be a significant hazard to navigation in water depths of about 200 ft.

23. The crater depths in the Diamond Point and Delta Point clays were similar for comparable charge weights and positions and were deeper than craters in loess and sand. Crater depths in the Sorrento clay, although greater than in sand, were about the same as those obtained in loess.

24. Crater widths were about the same for tests in sand, loess, and the clays at Diamond Point and Delta Point. In the Sorrento clay, crater widths were less than those for all other soils.

25. A comparison of typical results of cratering tests in clays is presented in the form of dimensionless profiles on the upper part of plate 73. The profiles show the results of charges detonated on the bottom in a scaled 30-ft water depth for the three clays tested by the Waterways Experiment Station. Shown also is a similar profile (Dahlgren) for a crater resulting from comparable tests involving charge weights of 600 and 4200 lbs, which were conducted in the Potomac River near Dahlgren Proving Grounds in connection with the Naval Ordnance Laboratory Project 152*. The latter data agree closely with the average profile for clays at Diamond and Delta Points.

26. On the lower part of plate 73 are dimensionless profiles for sand, loess, Sorrento clay, and the average of Dahlgren, Diamond Point and Delta Point clays. Craters at Sorrento, although of comparable depth with those in loess, had lip heights comparable with those of sand and widths which were less than for any other type soil.

27. Comparison of soil characteristics in table A with profiles on plate 73 indicates, generally, that similar craters are produced in soils with similar plasticity indexes and moisture contents (loess and Sorrento clay for example). It is believed that the clays described herein satisfactorily bracket those clays that may exist in various harbors. Knowledge of the origin and age of the deposit in a given

---

*Crater measurements were furnished gratuitously to the Waterways Experiment Station by Dr. E. Swift, Jr., and Mr. G. A. Young, NOL, Indian Head, Md.

harbor would aid considerably in determining which of the foregoing results should be used for extrapolations to charges of higher energy yields.

28. Taking the Diamond Point clay as a typical material, the effect of various water depths on cratering is shown on plate 74 for charges detonated at bottom and below bottom. The dimensionless plots indicate that water depth had little effect on crater size for either charge position.

## Abbreviations and Symbols

A cross-sectional area of crater (vertical plane section through ground zero) in sq ft

D depth of water in ft

d maximum depth of apparent crater in ft

h height of crater lip in ft

P any parameter in the general empirical formula $P = KW^n$, where K is a constant and n is the exponent of W

R horizontal distance from charge in ft

r radius of crater (w/2) in ft

V volume of crater in cu ft

W value of energy release, or weight of charge in lb

w width of crater in ft

w' width of crater lip in ft

X, Y standard rectangular coordinates from any designated point of origin in ft

Z charge position, distance from water surface to charge center of gravity expressed in terms of the total water depth

$\lambda$ $R/W^{1/3}$ (reduced distance)

# TABLES

TABLE 1

RESULTS OF CRATERING TESTS IN CLAY SOILS - 4-LB CHARGES

$D/W^{1/3} = 0.086$

| Charge Position (Z)* | Shot No. | Water Depth D(ft) | Crater Dimensions: Max Depth d (ft) | Crater Dimensions: Max Width w (ft) | Crater Dimensions: Height of Lip h (ft) | Crater Dimensions: Width of Lip w' (ft) | Reduced Crater Dimensions: $d/W^{1/3}$ | Reduced Crater Dimensions: $w/W^{1/3}$ | Reduced Crater Dimensions: $h/W^{1/3}$ | Reduced Crater Dimensions: $w'/W^{1/3}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| DIAMOND POINT | | | | | | | | | | |
| Charge Below Bottom (Z = -4.0D)** | 468 | 0.14 | 2.50 | 7.20 | 0.46 | 4.41 | 1.57 | 4.53 | 0.29 | 2.77 |
| | 469 | 0.14 | 2.66 | 6.70 | 0.54 | 4.65 | 1.67 | 4.21 | 0.34 | 2.92 |
| Arithmetic mean | | 0.14 | 2.58 | 6.95 | 0.50 | 4.53 | 1.62 | 4.37 | 0.32 | 2.85 |
| Charge at Bottom (Z = -1.0D) | 471 | 0.14 | 2.06 | 5.54 | 0.75 | 3.23 | 1.30 | 3.48 | 0.47 | 2.03 |
| | 472 | 0.14 | 2.10 | 6.02 | 0.39 | 2.99 | 1.32 | 3.79 | 0.25 | 1.88 |
| Arithmetic mean | | 0.14 | 2.08 | 5.78 | 0.57 | 3.11 | 1.31 | 3.64 | 0.36 | 1.96 |
| DELTA POINT | | | | | | | | | | |
| Charge Below Bottom (Z = -4.0D)** | 569 | 0.14 | 2.31 | 7.24 | 0.35 | 2.38 | 1.45 | 4.55 | 0.22 | 1.50 |
| | 570 | 0.14 | 2.49 | 7.44 | 0.41 | 2.28 | 1.57 | 4.68 | 0.26 | 1.43 |
| Arithmetic mean | | 0.14 | 2.40 | 7.34 | 0.38 | 2.33 | 1.51 | 4.62 | 0.24 | 1.47 |
| Charge at Bottom (Z = -1.0D) | 554 | 0.14 | 1.98 | 4.82 | 0.44 | 4.09 | 1.25 | 3.03 | 0.28 | 2.57 |
| | 555 | 0.14 | 2.10 | 5.14 | 0.46 | 3.93 | 1.32 | 3.23 | 0.29 | 2.47 |
| Arithmetic mean | | 0.14 | 2.04 | 4.98 | 0.45 | 4.01 | 1.29 | 3.13 | 0.29 | 2.52 |
| SORRENTO | | | | | | | | | | |
| Charge Below Bottom (Z = -4.0D)** | 0-11 | 0.14 | 1.89 | 7.48 | 0.17 | 0.76 | 1.19 | 4.70 | 0.11 | 0.48 |
| | 0-12 | 0.14 | 1.77 | 6.60 | 0.16 | 1.20 | 1.11 | 4.15 | 0.10 | 0.75 |
| Arithmetic mean | | 0.14 | 1.83 | 7.04 | 0.17 | 0.98 | 1.15 | 4.43 | 0.11 | 0.62 |
| Charge at Bottom (Z = -1.0D) | 0-9 | 0.14 | 1.44 | 4.30 | 0.18 | 1.85 | 0.91 | 2.70 | 0.11 | 1.16 |
| | 0-10 | 0.14 | 1.25 | 4.00 | 0.10 | 2.00 | 0.79 | 2.52 | 0.06 | 1.26 |
| Arithmetic mean | | 0.14 | 1.35 | 4.15 | 0.14 | 1.93 | 0.85 | 2.61 | 0.09 | 1.21 |

*Charge Position (Z) denotes, in terms of total water depth (D), the distance above or below the water surface to the charge center of gravity.
**Full-scale depth below bottom - 90 ft.

TABLE 2

RESULTS OF CRATERING TESTS IN CLAY SOILS - 32-LB CHARGES

$D/W^{1/3} = 0.088$

| Charge Position (Z)* | Shot No. | Water Depth D(ft) | Crater Dimensions: Max Depth d (ft) | Max Width w (ft) | Height of Lip h (ft) | Width of Lip w' (ft) | Reduced Crater Dimensions: $d/W^{1/3}$ | $w/W^{1/3}$ | $h/W^{1/3}$ | $w'/W^{1/3}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | DIAMOND POINT | | | | | |
| Charge Below Bottom (Z = -4.0D)** | 458<br>459 | 0.28<br>0.28 | 4.12<br>4.52 | 13.0<br>14.8 | 1.04<br>1.06 | 5.48<br>4.62 | 1.30<br>1.42 | 4.09<br>4.65 | 0.33<br>0.33 | 1.72<br>1.45 |
| Arithmetic mean | | 0.28 | 4.32 | 13.9 | 1.05 | 5.05 | 1.36 | 4.37 | 0.33 | 1.59 |
| Charge at Bottom (Z = -1.0D) | 461<br>462 | 0.28<br>0.28 | 3.98<br>3.94 | 11.6<br>10.9 | 0.89<br>0.94 | 4.18<br>4.57 | 1.25<br>1.24 | 3.65<br>3.43 | 0.28<br>0.30 | 1.31<br>1.44 |
| Arithmetic mean | | 0.28 | 3.96 | 11.3 | 0.92 | 4.38 | 1.25 | 3.54 | 0.29 | 1.38 |
| | | | | | DELTA POINT | | | | | |
| Charge Below Bottom (Z = -4.0D)** | 563<br>564 | 0.28<br>0.28 | 4.55<br>4.65 | 12.9<br>13.1 | 1.16<br>1.25 | 5.53<br>5.47 | 1.43<br>1.46 | 4.06<br>4.12 | 0.36<br>0.39 | 1.74<br>1.72 |
| Arithmetic mean | | 0.28 | 4.60 | 13.0 | 1.21 | 5.50 | 1.45 | 4.09 | 0.38 | 1.73 |
| Charge at Bottom (Z = -1.0D) | 558<br>559 | 0.28<br>0.28 | 4.20<br>3.71 | 9.30<br>10.4 | 1.04<br>1.00 | 6.30<br>6.85 | 1.32<br>1.17 | 2.92<br>3.27 | 0.33<br>0.31 | 1.98<br>2.15 |
| Arithmetic mean | | 0.28 | 3.96 | 9.85 | 1.02 | 6.58 | 1.25 | 3.10 | 0.32 | 2.07 |
| | | | | | SORRENTO | | | | | |
| Charge Below Bottom (Z = -4.0D)** | 0-7<br>0-8 | 0.28<br>0.28 | 5.01<br>4.91 | 12.1<br>11.9 | 1.01<br>0.72 | 3.95<br>4.05 | 1.58<br>1.54 | 3.81<br>3.74 | 0.32<br>0.23 | 1.24<br>1.27 |
| Arithmetic mean | | 0.28 | 4.96 | 12.0 | 0.87 | 4.00 | 1.56 | 3.78 | 0.28 | 1.26 |
| Charge at Bottom (Z = -1.0D) | 0-5<br>0-6 | 0.28<br>0.28 | 2.99<br>2.80 | 11.2<br>8.80 | 0.77<br>0.48 | 3.90<br>3.60 | 0.94<br>0.88 | 3.52<br>2.77 | 0.24<br>0.15 | 1.23<br>1.13 |
| Arithmetic mean | | 0.28 | 2.90 | 10.0 | 0.63 | 3.75 | 0.91 | 3.15 | 0.20 | 1.18 |

*Charge Position (Z) denotes, in terms of total water depth (D), the distance above or below the water surface to the charge center of gravity.
**Full-scale depth below bottom - 90 ft.

TABLE 3

RESULTS OF CRATERING TESTS IN CLAY (DIAMOND POINT)

$D/W^{1/3} = 0.175$

| Charge Position (Z)* | Shot No. | Water Depth D(ft) | Crater Dimensions: Max Depth d (ft) | Max Width w (ft) | Height of Lip h (ft) | Width of Lip w' (ft) | Reduced Crater Dimensions: $d/W^{1/3}$ | $w/W^{1/3}$ | $h/W^{1/3}$ | $w'/W^{1/3}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **4-LB CHARGES** | | | | | | | | | | |
| Charge Below Bottom (Z = -2.5D)** | 507<br>533 | 0.28<br>0.28 | 2.64<br>2.56 | 7.60<br>7.40 | 0.72<br>0.58 | 3.30<br>3.20 | 1.66<br>1.61 | 4.78<br>4.65 | 0.45<br>0.36 | 2.08<br>2.01 |
| Arithmetic mean | | 0.28 | 2.60 | 7.50 | 0.65 | 3.25 | 1.64 | 4.72 | 0.41 | 2.04 |
| Charge at Bottom (Z = -1.0D) | 509<br>510 | 0.28<br>0.28 | 2.31<br>2.34 | 6.04<br>6.16 | 0.52<br>0.58 | 2.73<br>2.67 | 1.45<br>1.47 | 3.80<br>3.87 | 0.33<br>0.36 | 1.72<br>1.68 |
| Arithmetic mean | | 0.28 | 2.33 | 6.10 | 0.55 | 2.70 | 1.46 | 3.84 | 0.35 | 1.70 |
| **32-LB CHARGES** | | | | | | | | | | |
| Charge Below Bottom (Z = -2.5D)** | 527<br>528 | 0.56<br>0.56 | 4.19<br>4.43 | 15.5<br>15.5 | 1.23<br>0.92 | 5.27<br>5.23 | 1.32<br>1.39 | 4.87<br>4.87 | 0.39<br>0.29 | 1.66<br>1.64 |
| Arithmetic mean | | 0.56 | 4.31 | 15.5 | 1.08 | 5.25 | 1.36 | 4.87 | 0.34 | 1.65 |
| Charge at Bottom (Z = -1.0D) | 530<br>531 | 0.56<br>0.56 | 3.56<br>3.39 | 11.3<br>12.3 | 0.93<br>0.76 | 5.37<br>4.87 | 1.12<br>1.07 | 3.55<br>3.87 | 0.29<br>0.24 | 1.69<br>1.53 |
| Arithmetic mean | | 0.56 | 3.48 | 11.8 | 0.85 | 5.12 | 1.10 | 3.71 | 0.27 | 1.61 |

*Charge position (Z) denotes, in terms of total water depth (D), the distance above or below the water surface to the charge center of gravity.
**Full-scale depth below bottom = 90 ft.

1

CONFIDENTIAL
Security Information

**TABLE 4.**

**RESULTS OF CRATERING TESTS IN CLAY (DIAMOND POINT)**

$D/W^{1/3} = 0.292$

| Charge Position (Z)* | Shot No. | Water Depth D(ft) | Crater Dimensions: Max Depth d (ft) | Max Width w (ft) | Height of Lip h (ft) | Width of Lip w' (ft) | Reduced Crater Dimensions: $d/W^{1/3}$ | $w/W^{1/3}$ | $h/W^{1/3}$ | $w'/W^{1/3}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **4-LB CHARGES** | | | | | | | | | | |
| Charge Below Bottom (Z = -1.9D)** | 513<br>514 | 0.46<br>0.46 | 2.74<br>2.68 | 7.42<br>7.34 | 0.53<br>0.70 | 2.79<br>2.83 | 1.72<br>1.68 | 4.67<br>4.62 | 0.33<br>0.44 | 1.75<br>1.78 |
| Arithmetic mean | | 0.46 | 2.71 | 7.38 | 0.62 | 2.81 | 1.70 | 4.65 | 0.39 | 1.77 |
| Charge at Bottom (Z = -1.0D) | 519<br>520 | 0.46<br>0.46 | 2.21<br>2.22 | 6.34<br>5.34 | 0.46<br>0.55 | 2.83<br>3.68 | 1.39<br>1.40 | 3.99<br>3.36 | 0.29<br>0.35 | 1.78<br>2.31 |
| Arithmetic mean | | 0.46 | 2.22 | 5.84 | 0.51 | 3.26 | 1.40 | 3.68 | 0.32 | 2.05 |
| **32-LB CHARGES** | | | | | | | | | | |
| Charge Below Bottom (Z = -1.9D)** | 521<br>522 | 0.93<br>0.93 | 3.84<br>3.87 | 15.6<br>15.7 | 1.13<br>1.05 | 3.95<br>3.65 | 1.21<br>1.22 | 4.91<br>4.94 | 0.36<br>0.33 | 1.24<br>1.15 |
| Arithmetic mean | | 0.93 | 3.86 | 15.7 | 1.09 | 3.80 | 1.22 | 4.93 | 0.35 | 1.20 |
| Charge at Bottom (Z = -1.0D) | 525<br>526 | 0.93<br>0.93 | 3.14<br>3.40 | 13.0<br>13.4 | 0.82<br>0.86 | 4.50<br>3.80 | 0.99<br>1.07 | 4.09<br>4.21 | 0.26<br>0.27 | 1.42<br>1.19 |
| Arithmetic mean | | 0.93 | 3.27 | 13.2 | 0.84 | 4.15 | 1.03 | 4.15 | 0.27 | 1.31 |

*Charge Position (Z) denotes, in terms of total water depth (D), the distance above or below the water surface to the charge center of gravity.
**Full-scale depth below bottom - 90 ft.

CONFIDENTIAL
Security Information

TABLE 5

RESULTS OF CRATERING TESTS IN CLAY SOILS - 4-LB CHARGES

$D/W^{1/3} = 0.585$

| Charge Position (Z)* | Shot No. | Water Depth D(ft) | Crater Dimensions: Max Depth d (ft) | Max Width w (ft) | Height of Lip h (ft) | Width of Lip w' (ft) | Reduced Crater Dimensions: $d/W^{1/3}$ | $w/W^{1/3}$ | $h/W^{1/3}$ | $w'/W^{1/3}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | DIAMOND POINT | | | | | |
| Charge Below Bottom (Z = -1.45D)** | 492<br>493 | 0.93<br>0.93 | 2.85<br>2.46 | 7.74<br>7.64 | 0.50<br>0.53 | 2.88<br>2.93 | 1.79<br>1.55 | 4.87<br>4.81 | 0.31<br>0.33 | 1.82<br>1.84 |
| Arithmetic mean | | 0.93 | 2.66 | 7.69 | 0.52 | 2.90 | 1.67 | 4.84 | 0.32 | 1.83 |
| Charge at Bottom (Z = -1.0D) | 497<br>498 | 0.93<br>0.93 | 2.36<br>2.18 | 6.66<br>5.70 | 0.40<br>0.41 | 3.42<br>3.90 | 1.48<br>1.37 | 4.19<br>3.58 | 0.25<br>0.26 | 2.15<br>2.45 |
| Arithmetic mean | | 0.93 | 2.27 | 6.18 | 0.41 | 3.66 | 1.43 | 3.89 | 0.26 | 2.30 |
| Charge at Mid-depth (Z = -0.5D) | 500<br>501 | 0.93<br>0.93 | 1.76<br>1.85 | 4.54<br>6.00 | 0.36<br>0.30 | 3.73<br>3.00 | 1.11<br>1.16 | 2.86<br>3.77 | 0.23<br>0.19 | 2.35<br>1.89 |
| Arithmetic mean | | 0.93 | 1.81 | 5.27 | 0.33 | 3.37 | 1.14 | 3.32 | 0.21 | 2.12 |
| | | | | | DELTA POINT | | | | | |
| Charge at Bottom (Z = -1.0D) | 551<br>552 | 0.93<br>0.93 | 2.39<br>2.31 | 7.04<br>7.44 | 0.32<br>0.34 | 3.98<br>3.78 | 1.50<br>1.45 | 4.43<br>4.68 | 0.20<br>0.21 | 2.50<br>2.38 |
| Arithmetic mean | | 0.93 | 2.35 | 7.24 | 0.33 | 3.88 | 1.48 | 4.56 | 0.21 | 2.44 |
| | | | | | SORRENTO | | | | | |
| Charge Below Bottom (Z = -1.45D)** | 0-15<br>0-16 | 0.93<br>0.93 | 1.18<br>1.37 | 6.30<br>7.82 | 0.37<br>0.28 | 3.35<br>2.59 | 0.74<br>0.86 | 3.96<br>4.92 | 0.23<br>0.18 | 2.11<br>1.63 |
| Arithmetic mean | | 0.93 | 1.28 | 7.06 | 0.33 | 2.97 | 0.80 | 4.44 | 0.21 | 1.87 |
| Charge at Bottom (Z = -1.0D) | 0-13<br>0-14 | 0.93<br>0.93 | 1.30<br>1.26 | 6.05<br>5.95 | 0.15<br>0.13 | 1.67<br>1.83 | 0.82<br>0.79 | 3.81<br>3.74 | 0.09<br>0.08 | 1.05<br>1.15 |
| Arithmetic mean | | 0.93 | 1.28 | 6.00 | 0.14 | 1.75 | 0.81 | 3.78 | 0.09 | 1.10 |

*Charge Position (Z) denotes, in terms of total water depth (D), the distance above or below the water surface to the charge center of gravity.
**Full-scale depth below bottom = 90 ft.

TABLE 6

RESULTS OF CRATERING TESTS IN CLAY SOILS - 32-LB CHARGES

$D/W^{1/3} = 0.585$

| | | | Crater Dimensions | | | | Reduced Crater Dimensions | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Charge Position (Z)* | Shot No. | Water Depth D(ft) | Max Depth d (ft) | Max Width w (ft) | Height of Lip h (ft) | Width of Lip w' (ft) | $d/W^{1/3}$ | $w/W^{1/3}$ | $h/W^{1/3}$ | $w'/W^{1/3}$ |
| **DIAMOND POINT** | | | | | | | | | | |
| Charge Below Bottom (Z = -1.45D)** | 488 | 1.85 | 4.15 | 15.8 | 0.84 | 7.12 | 1.31 | 4.97 | 0.26 | 2.24 |
| | 504 | 1.85 | 4.20 | 15.1 | 1.02 | 7.44 | 1.32 | 4.75 | 0.32 | 2.34 |
| Arithmetic mean | | 1.85 | 4.18 | 15.4 | 0.93 | 7.28 | 1.32 | 4.86 | 0.29 | 2.29 |
| Charge at Bottom (Z = -1.0D) | 480 | 1.85 | 3.18 | 13.5 | 0.77 | 3.25 | 1.00 | 4.25 | 0.24 | 1.02 |
| | 482 | 1.85 | 3.33 | 12.3 | 0.56 | 3.85 | 1.05 | 3.87 | 0.18 | 1.21 |
| Arithmetic mean | | 1.85 | 3.26 | 12.9 | 0.67 | 3.55 | 1.03 | 4.06 | 0.21 | 1.12 |
| Charge at Mid-depth (Z = -0.5D) | 477 | 1.85 | 2.60 | 9.28 | 0.61 | 4.36 | 0.82 | 2.92 | 0.19 | 1.37 |
| | 479 | 1.85 | 2.72 | 9.76 | 0.56 | 4.12 | 0.86 | 3.07 | 0.18 | 1.30 |
| Arithmetic mean | | 1.85 | 2.66 | 9.52 | 0.59 | 4.24 | 0.84 | 3.00 | 0.19 | 1.34 |
| **DELTA POINT** | | | | | | | | | | |
| Charge at Bottom (Z = -1.0D) | 560 | 1.85 | 4.40 | 12.8 | 0.90 | 6.10 | 1.38 | 4.03 | 0.28 | 1.92 |
| | 561 | 1.85 | 4.23 | 13.4 | 0.97 | 5.80 | 1.33 | 4.21 | 0.31 | 1.82 |
| Arithmetic mean | | 1.85 | 4.32 | 13.1 | 0.94 | 5.95 | 1.36 | 4.12 | 0.30 | 1.87 |
| **SORRENTO** | | | | | | | | | | |
| Charge Below Bottom (Z = -1.45D)** | 0-3 | 1.85 | 2.20 | 12.0 | 0.91 | 4.00 | 0.69 | 3.77 | 0.29 | 1.26 |
| | 0-4 | 1.85 | 2.10 | 10.0 | 1.00 | 5.00 | 0.66 | 3.14 | 0.31 | 1.57 |
| Arithmetic mean | | 1.85 | 2.15 | 11.0 | 0.96 | 4.50 | 0.68 | 3.46 | 0.30 | 1.42 |
| Charge at Bottom (Z = -1.0D) | 0-1 | 1.85 | 2.55 | 9.60 | 0.80 | 5.20 | 0.80 | 3.02 | 0.25 | 1.64 |
| | 0-2 | 1.85 | 2.98 | 11.4 | 0.33 | 3.82 | 0.94 | 3.58 | 0.10 | 1.20 |
| Arithmetic mean | | 1.85 | 2.77 | 10.5 | 0.57 | 4.51 | 0.87 | 3.30 | 0.18 | 1.42 |

*Charge Position (Z) denotes, in terms of total water depth (D), the distance above or below the water surface to the charge center of gravity.
**Full-scale depth below bottom - 90 ft.

TABLE 7

RESULTS OF CRATERING TESTS IN CLAY SOILS

$D/W^{1/3} = 0.088$

| Crater Parameter* | Values for $W^{1/3}$ Law K | n | Mean Experimental Values K | n |
|---|---|---|---|---|
| | DIAMOND POINT CLAY - CHARGE BELOW BOTTOM (Z = -4.0D) | | | |
| Width - w | 4.37 | 0.33 | 4.38 | 0.33 |
| Depth - d | 1.49 | 0.33 | 1.83 | 0.25 |
| Lip Height - h | 0.33 | 0.33 | 0.30 | 0.36 |
| Area - A | 3.84 | 0.67 | 4.89 | 0.56 |
| Volume - V | 9.34 | 1.00 | 12.4 | 0.88 |
| | DIAMOND POINT CLAY - CHARGE AT BOTTOM (Z = -1.0D) | | | |
| Width - w | 3.59 | 0.33 | 3.70 | 0.32 |
| Depth - d | 1.28 | 0.33 | 1.35 | 0.31 |
| Lip Height - h | 0.32 | 0.33 | 0.41 | 0.23 |
| Area - A | 3.01 | 0.67 | 3.11 | 0.65 |
| Volume - V | 6.28 | 1.00 | 6.21 | 1.00 |
| | DELTA POINT CLAY - CHARGE BELOW BOTTOM (Z = -4.0D) | | | |
| Width - w | 4.36 | 0.33 | 5.01 | 0.27 |
| Depth - d | 1.48 | 0.33 | 1.56 | 0.31 |
| Lip Height - h | 0.31 | 0.33 | 0.18 | 0.56 |
| Area - A | 3.63 | 0.67 | 3.29 | 0.71 |
| Volume - V | 8.57 | 1.00 | 7.74 | 1.04 |
| | DELTA POINT CLAY - CHARGE AT BOTTOM (Z = -1.0D) | | | |
| Width - w | 3.12 | 0.33 | 3.12 | 0.33 |
| Depth - d | 1.27 | 0.33 | 1.31 | 0.32 |
| Lip Height - h | 0.30 | 0.33 | 0.26 | 0.39 |
| Area - A | 2.61 | 0.67 | 2.58 | 0.67 |
| Volume - V | 4.69 | 1.00 | 4.48 | 1.02 |
| | SORRENTO CLAY - CHARGE BELOW BOTTOM (Z = -4.0D) | | | |
| Width - w | 4.10 | 0.33 | 4.93 | 0.26 |
| Depth - d | 1.36 | 0.33 | 0.94 | 0.48 |
| Lip Height - h | 0.19 | 0.33 | 0.06 | 0.78 |
| Area - A | 3.25 | 0.67 | 2.61 | 0.75 |
| Volume - V | 7.31 | 1.00 | 7.07 | 1.01 |
| | SORRENTO CLAY - CHARGE AT BOTTOM (Z = -1.0D) | | | |
| Width - w | 2.88 | 0.33 | 2.31 | 0.42 |
| Depth - d | 0.88 | 0.33 | 0.81 | 0.37 |
| Lip Height - h | 0.15 | 0.33 | 0.05 | 0.72 |
| Area - A | 1.30 | 0.67 | 0.88 | 0.82 |
| Volume - V | 1.92 | 1.00 | 0.93 | 1.28 |

$*P = KW^n$

P = specified parameter
K = constant
W = charge weight in lbs
n = exponent of charge weight

Charge Position (Z) denotes, in terms of total water depth (D), the distance above or below the water surface to the charge center of gravity.

TABLE 8

RESULTS OF CRATERING TESTS IN CLAY

DIAMOND POINT

$D/W^{1/3}$ = 0.175 and 0.292

| Crater Parameter* | Values for $W^{1/3}$ Law K | Values for $W^{1/3}$ Law n | Mean Experimental Values K | Mean Experimental Values n |
|---|---|---|---|---|
| | $D/W^{1/3}$ = 0.175 | | | |
| | CHARGE BELOW BOTTOM (Z = -2.5D) | | | |
| Width - w | 4.80 | 0.33 | 4.62 | 0.35 |
| Depth - d | 1.50 | 0.33 | 1.86 | 0.24 |
| Lip Height - h | 0.38 | 0.33 | 0.46 | 0.24 |
| Area - A | 4.11 | 0.67 | 5.89 | 0.51 |
| Volume - V | 10.6 | 1.00 | 16.3 | 0.82 |
| | CHARGE AT BOTTOM (Z = -1.0D) | | | |
| Width - w | 3.78 | 0.33 | 3.93 | 0.32 |
| Depth - d | 1.28 | 0.33 | 1.78 | 0.19 |
| Lip Height - h | 0.31 | 0.33 | 0.41 | 0.21 |
| Area - A | 2.84 | 0.67 | 4.82 | 0.44 |
| Volume - V | 5.92 | 1.00 | 11.9 | 0.69 |
| | $D/W^{1/3}$ = 0.292 | | | |
| | CHARGE BELOW BOTTOM (Z = -1.9D) | | | |
| Width - w | 4.79 | 0.33 | 4.46 | 0.36 |
| Depth - d | 1.46 | 0.33 | 2.14 | 0.17 |
| Lip Height - h | 0.37 | 0.33 | 0.42 | 0.27 |
| Area - A | 4.02 | 0.67 | 6.97 | 0.43 |
| Volume - V | 10.6 | 1.00 | 18.5 | 0.76 |
| | CHARGE AT BOTTOM (Z = -1.0D) | | | |
| Width - w | 3.92 | 0.33 | 3.39 | 0.39 |
| Depth - d | 1.22 | 0.33 | 1.71 | 0.19 |
| Lip Height - h | 0.29 | 0.33 | 0.36 | 0.24 |
| Area - A | 2.70 | 0.67 | 3.72 | 0.53 |
| Volume - V | 5.76 | 1.00 | 6.87 | 0.93 |

*$P = KW^n$

P = specified parameter
K = constant
W = charge weight in lbs
n = exponent of charge weight

Charge Position (Z) denotes, in terms of total water depth (D), the distance above or below the water surface to the charge center of gravity.

TABLE 9

RESULTS OF CRATERING TESTS IN CLAY SOILS

$D/W^{1/3} = 0.585$

| Crater Parameter* | Values for $W^{1/3}$ Law K | n | Mean Experimental Values K | n |
|---|---|---|---|---|
| | | DIAMOND POINT CLAY - CHARGE BELOW BOTTOM (Z = -1.45D) | | |
| Width - w | 4.84 | 0.33 | 4.84 | 0.33 |
| Depth - d | 1.50 | 0.33 | 1.97 | 0.22 |
| Lip Height - h | 0.31 | 0.33 | 0.35 | 0.28 |
| Area - A | 4.24 | 0.67 | 5.61 | 0.55 |
| Volume - V | 11.1 | 1.00 | 15.4 | 0.87 |
| | | DIAMOND POINT CLAY - CHARGE AT BOTTOM (Z = -1.0D) | | |
| Width - w | 3.98 | 0.33 | 3.78 | 0.35 |
| Depth - d | 1.23 | 0.33 | 1.78 | 0.17 |
| Lip Height - h | 0.24 | 0.33 | 0.30 | 0.24 |
| Area - A | 2.77 | 0.67 | 3.93 | 0.52 |
| Volume - V | 5.96 | 1.00 | 7.75 | 0.89 |
| | | DIAMOND POINT CLAY - CHARGE AT MID-DEPTH (Z = -0.5D) | | |
| Width - w | 3.16 | 0.33 | 3.55 | 0.28 |
| Depth - d | 0.99 | 0.33 | 1.40 | 0.19 |
| Lip Height - h | 0.20 | 0.33 | 0.22 | 0.28 |
| Area - A | 1.88 | 0.67 | 2.37 | 0.57 |
| Volume - V | 3.30 | 1.00 | 4.14 | 0.90 |
| | | DELTA POINT CLAY - CHARGE AT BOTTOM (Z = -1.0D) | | |
| Width - w | 4.34 | 0.33 | 4.88 | 0.29 |
| Depth - d | 1.42 | 0.33 | 1.57 | 0.29 |
| Lip Height - h | 0.26 | 0.33 | 0.16 | 0.50 |
| Area - A | 3.25 | 0.67 | 3.23 | 0.67 |
| Volume - V | 7.07 | 1.00 | 7.08 | 1.00 |
| | | SORRENTO CLAY - CHARGE BELOW BOTTOM (Z = -1.45D) | | |
| Width - w | 3.95 | 0.33 | 5.25 | 0.21 |
| Depth - d | 0.74 | 0.33 | 0.91 | 0.25 |
| Lip Height - h | 0.26 | 0.33 | 0.16 | 0.51 |
| Area - A | 1.55 | 0.67 | 2.13 | 0.53 |
| Volume - V | 3.28 | 1.00 | 5.56 | 0.77 |
| | | SORRENTO CLAY - CHARGE AT BOTTOM (Z = -1.0D) | | |
| Width - w | 3.54 | 0.33 | 4.13 | 0.27 |
| Depth - d | 0.84 | 0.33 | 0.76 | 0.37 |
| Lip Height - h | 0.13 | 0.33 | 0.05 | 0.68 |
| Area - A | 1.46 | 0.67 | 1.31 | 0.71 |
| Volume - V | 2.57 | 1.00 | 2.36 | 1.03 |

$*P = KW^n$

P = specified parameter
K = constant
W = charge weight in lbs
n = exponent of charge weight

Charge Position (Z) denotes, in terms of total water depth (D), the distance above or below the water surface to the charge center of gravity.

# PHOTOGRAPHS

Crater formed by 3[illegible]-lb charge detonated at [illegible] (Di[illegible] Point)
Scaled water depth, [illegible]

PHOTOGRAPH 1

PHOTOGRAPH 2

[illegible] -lb [illegible] detonated at bottom ([illegible])
[illegible] water depth, [illegible] ft

PHOTOGRAPH 3

PHOTOGRAPH 4

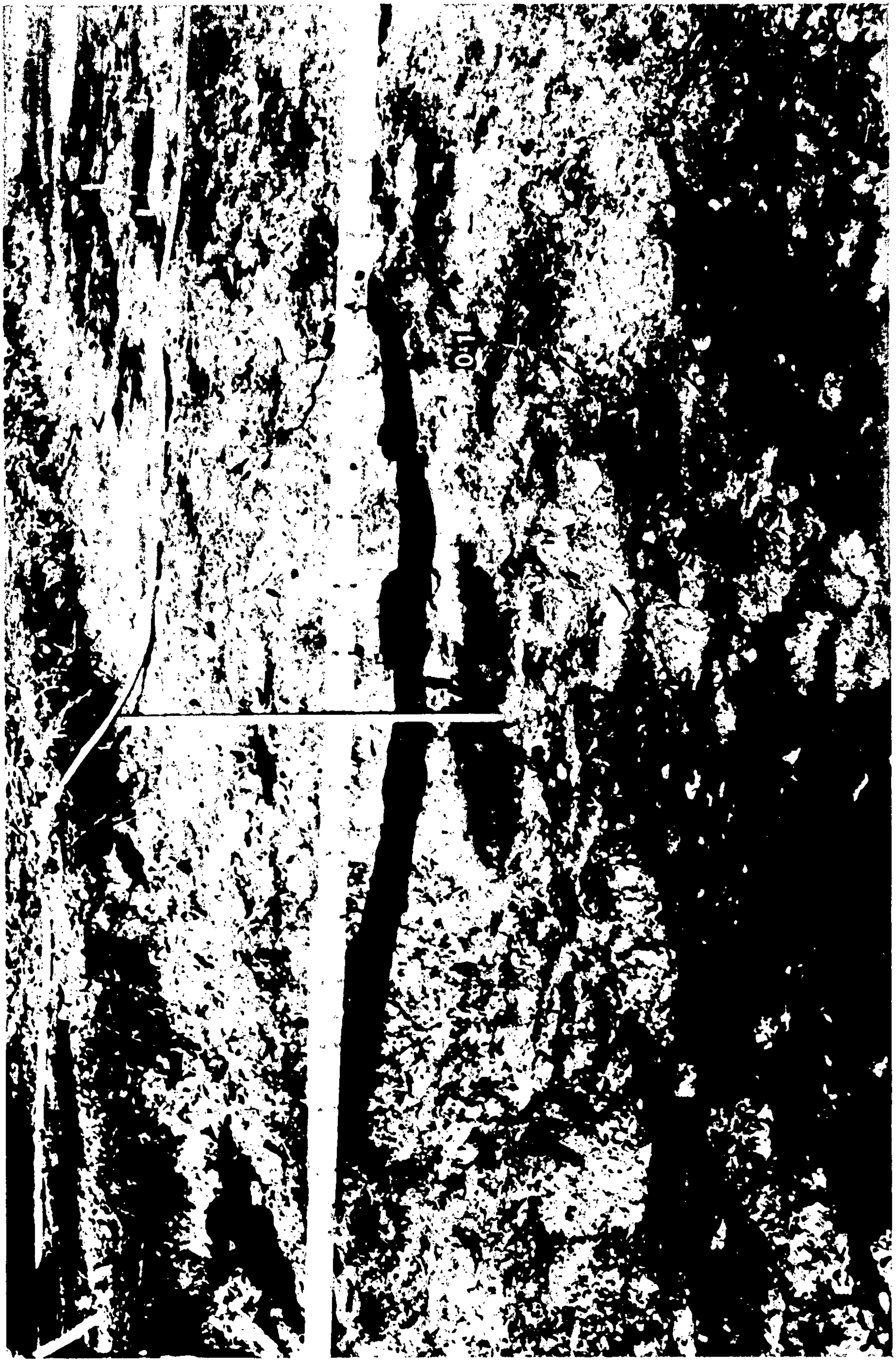
Crater formed by 32-lb charge detonated at bottom (Diamond Point)
Scaled water depth, 200 ft



PHOTOGRAPH 5


Crater formed by 32-lb charge detonated at [illegible]
Scaled water depth, [illegible]

PHOTOGRAPH 6



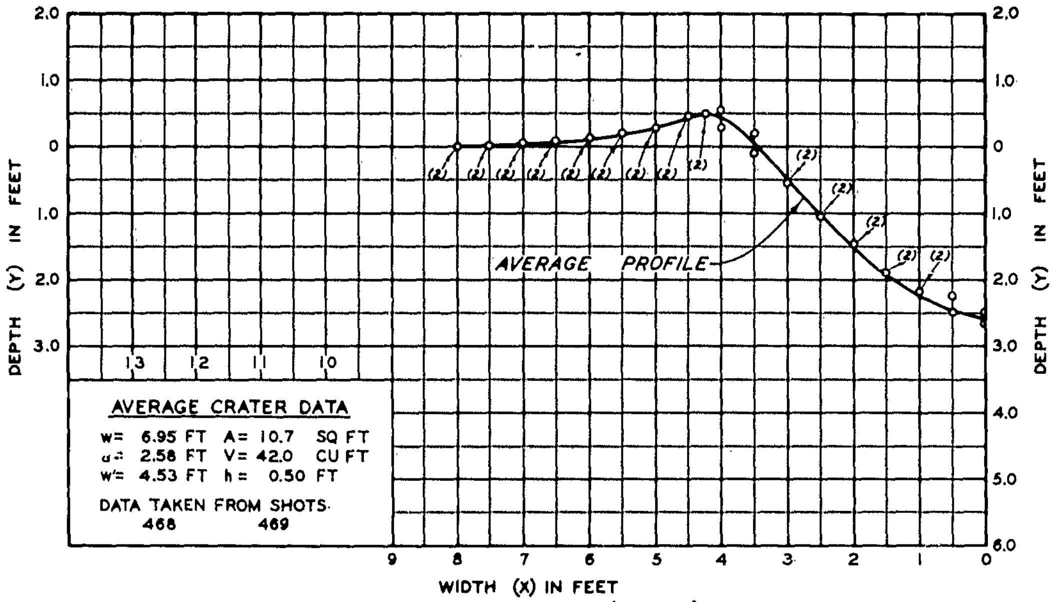

Crater formed by 32-lb charge detonated at bottom (Sorrento)
Scaled water depth, 200 ft



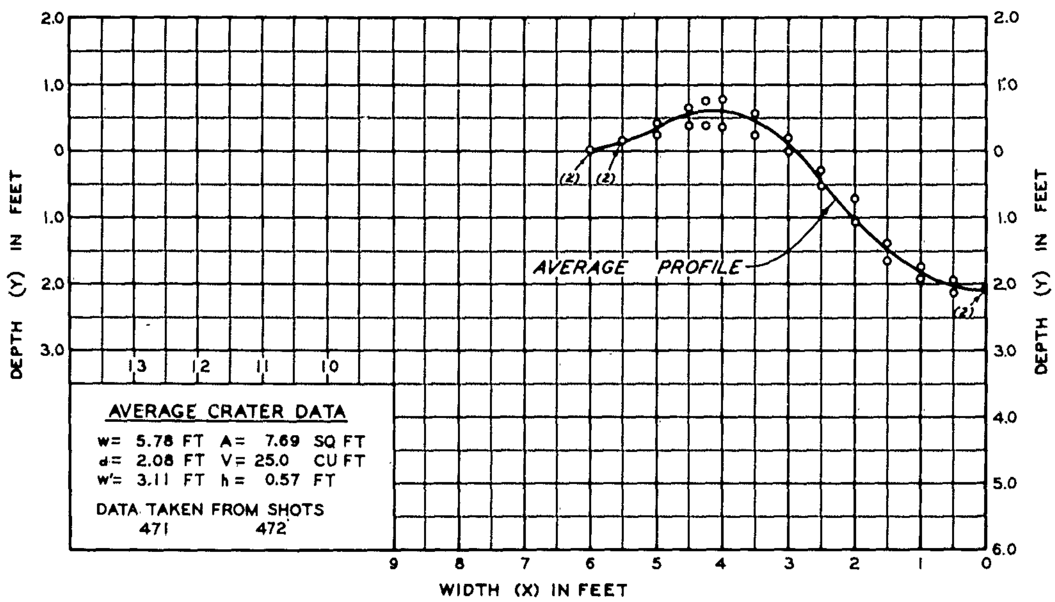
PHOTOGRAPH 7

# PLATES

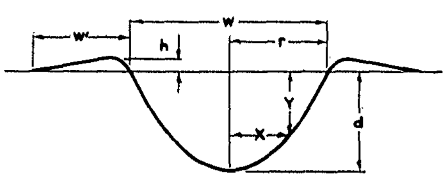
## PLATES 1 - 27
SCALED WATER DEPTH - 30 FT.




CHARGE BELOW BOTTOM (Z=-4.0D)




CHARGE AT BOTTOM (Z=-1.0 D)



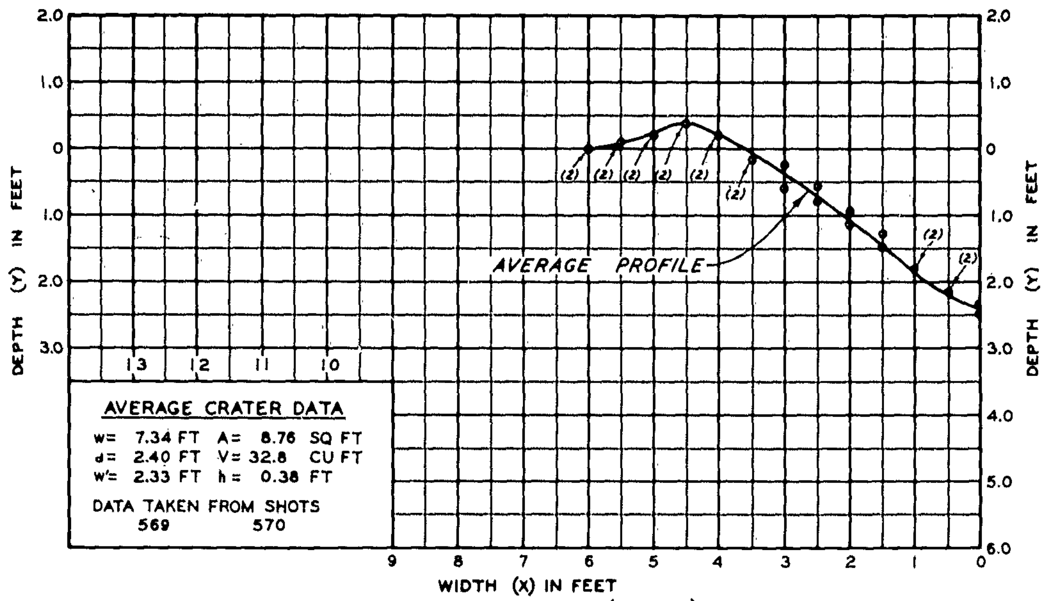

CRATER DIMENSIONS

## HALF-CRATER PROFILES

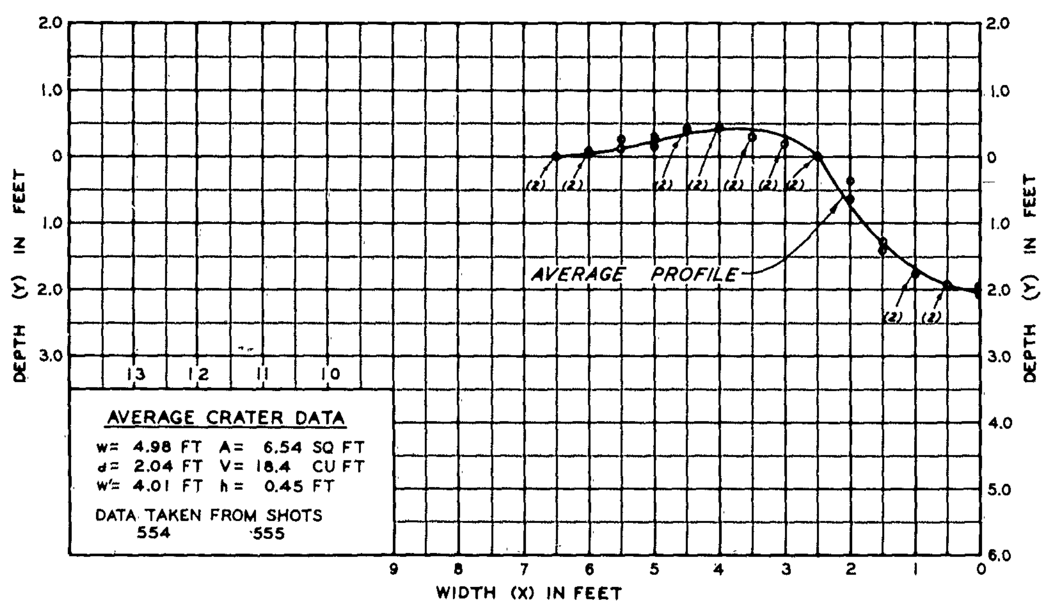
DIAMOND POINT CLAY

CHARGE WEIGHT - 4 LB

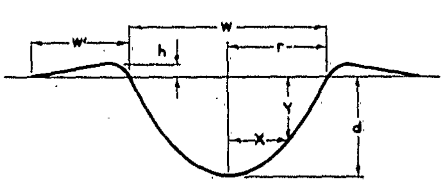
$D/W^{\frac{1}{3}} = 0.088$




CHARGE BELOW BOTTOM (Z=-4.0D)




CHARGE AT BOTTOM (Z=-1.0 D)




CRATER DIMENSIONS

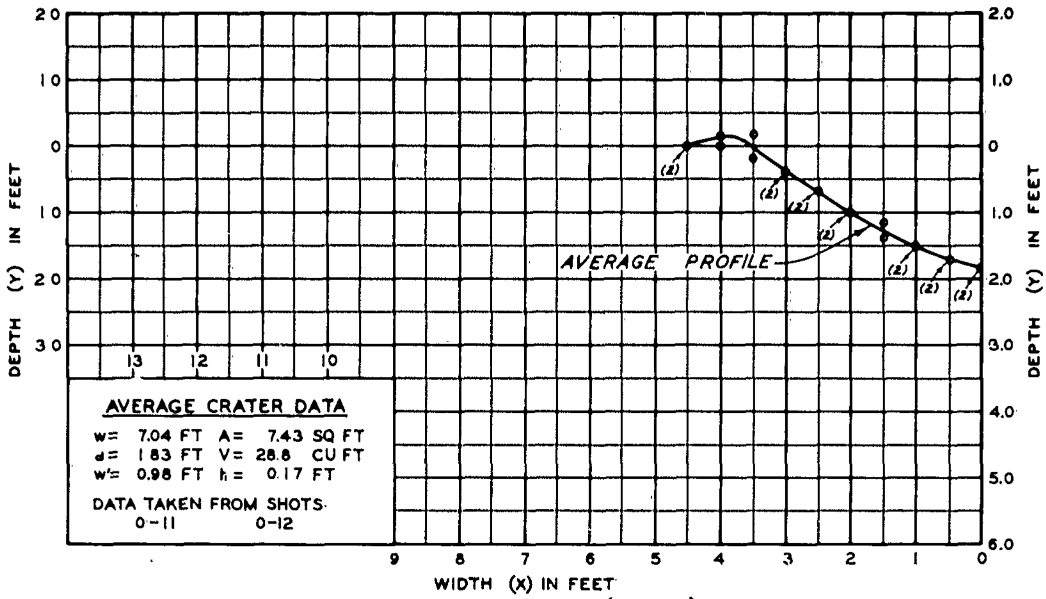
## HALF-CRATER PROFILES

DELTA POINT CLAY

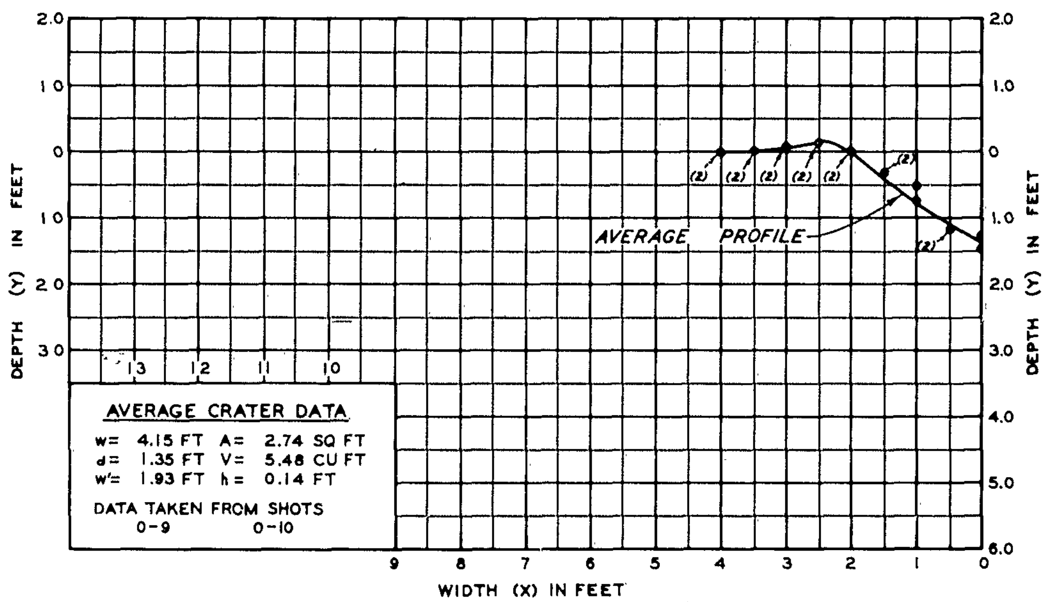
CHARGE WEIGHT – 4 LB

$D/W^{\frac{1}{3}} = 0.088$

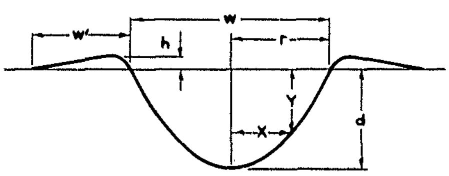
PLATE 2




CHARGE BELOW BOTTOM (Z=-4.0D)




CHARGE AT BOTTOM (Z=-1.0 D)



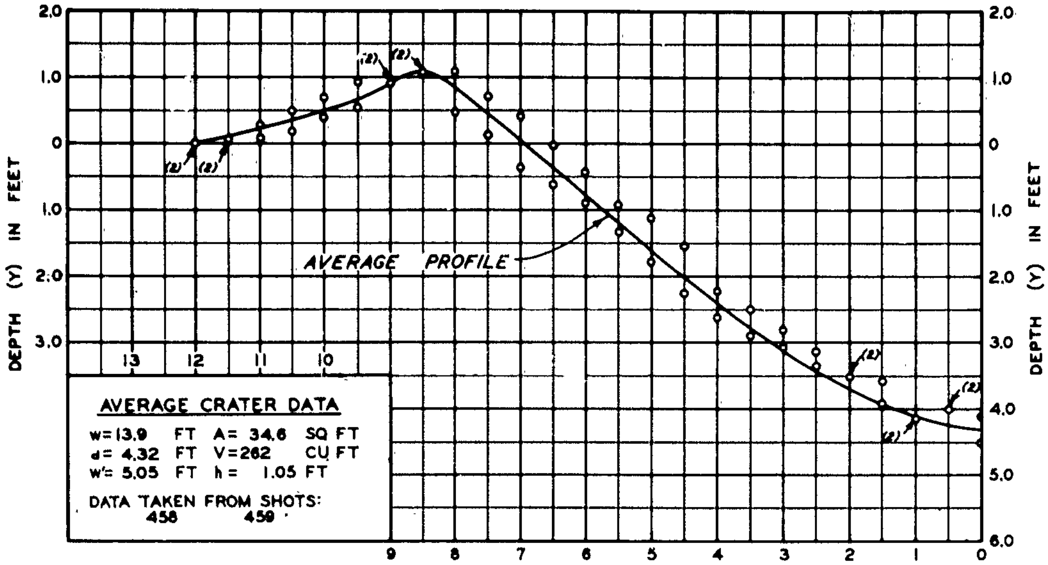

CRATER DIMENSIONS

## HALF-CRATER PROFILES

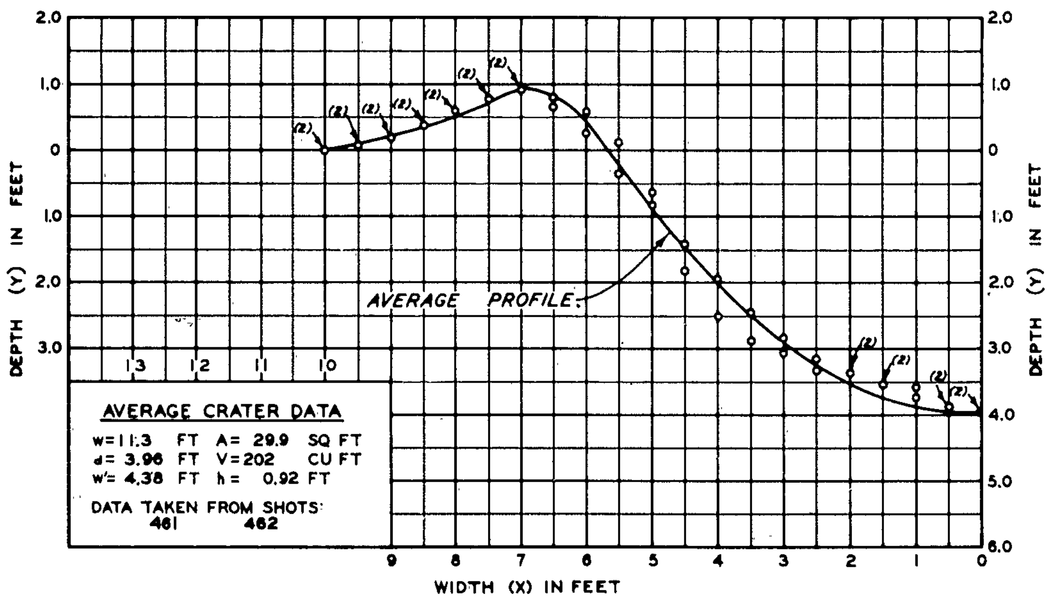
SORRENTO CLAY

CHARGE WEIGHT – 4 LB

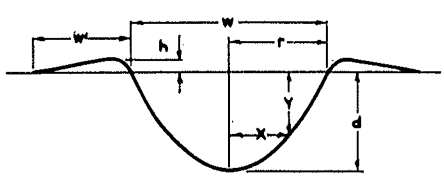
$D/W^{\frac{1}{3}} = 0.088$



CHARGE BELOW BOTTOM (Z=-4.0D)



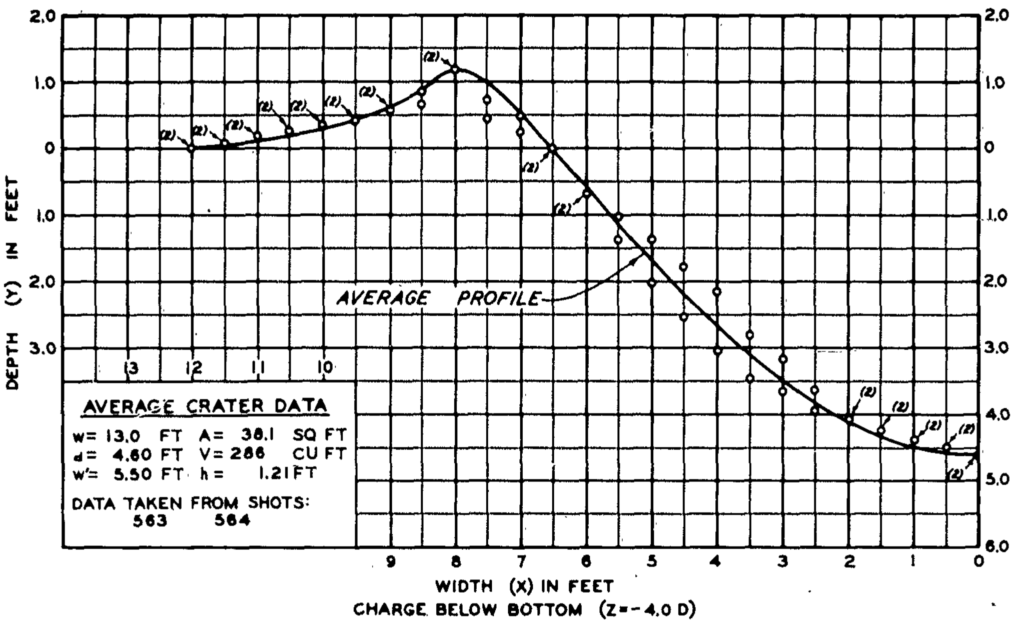
CHARGE AT BOTTOM (Z=-1.0 D)

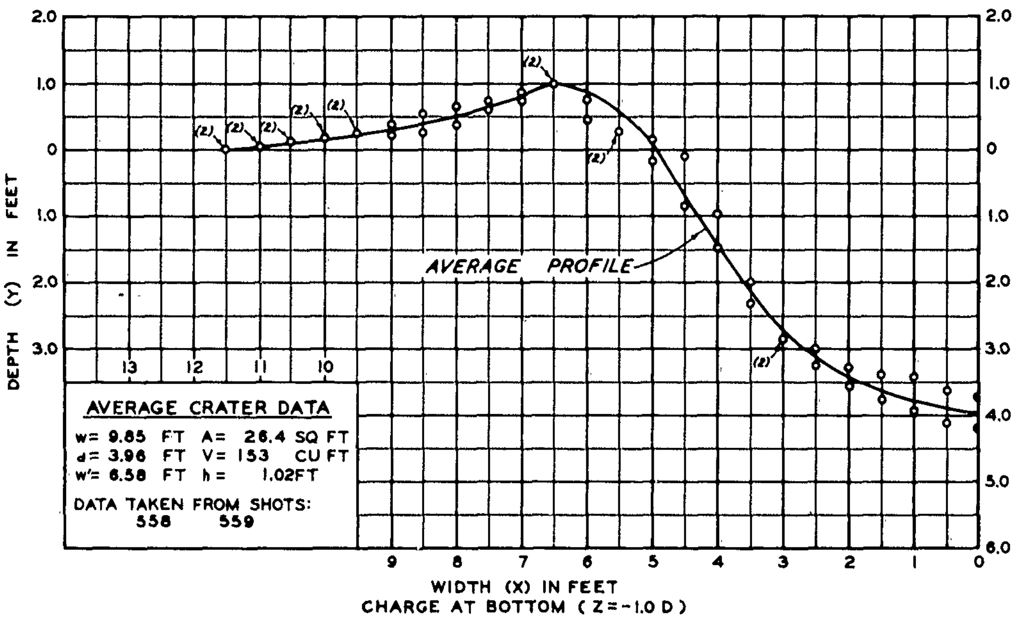


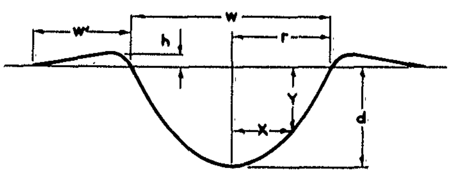
CRATER DIMENSIONS

## HALF-CRATER PROFILES
DIAMOND POINT CLAY
CHARGE WEIGHT - 32 LB
$D/W^{1/3} = 0.088$

PLATE 4



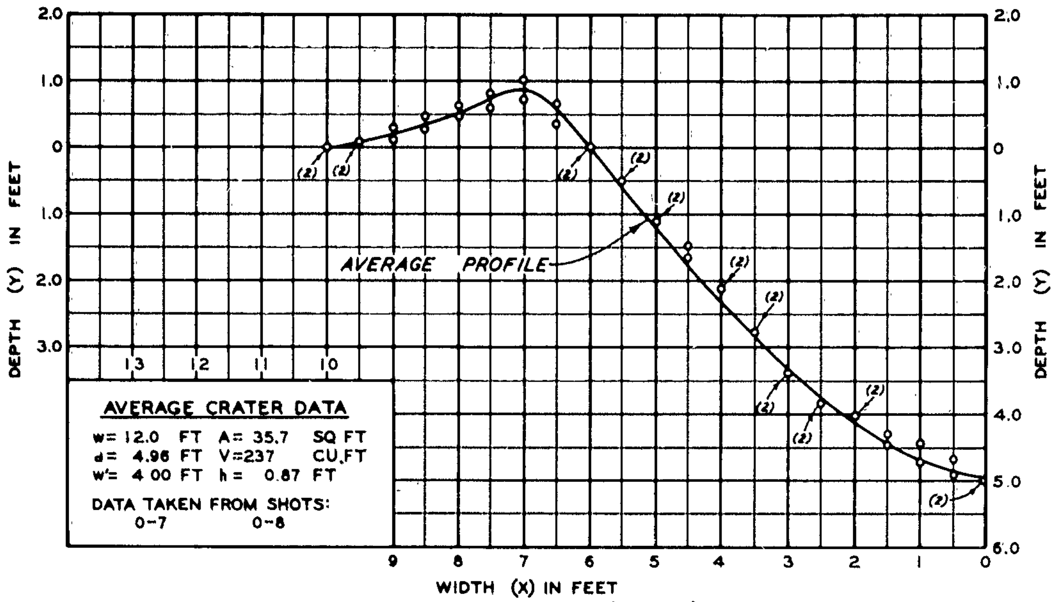




CRATER DIMENSIONS

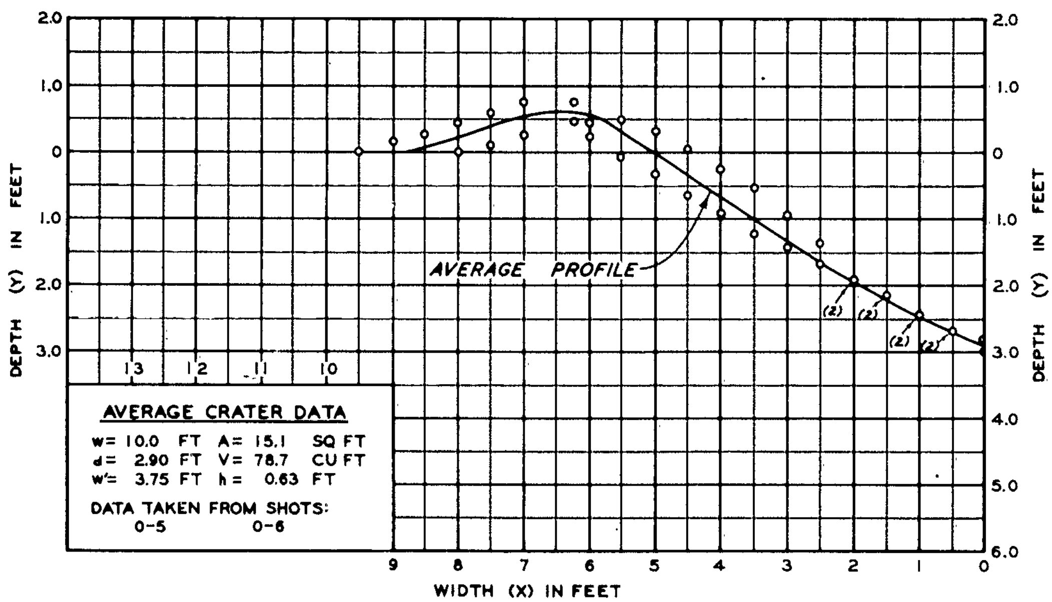
## HALF-CRATER PROFILES

DELTA POINT CLAY
CHARGE WEIGHT-32 LB

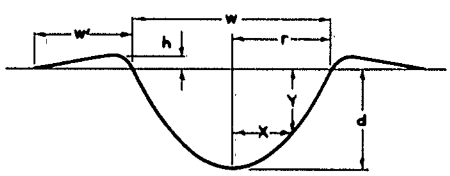
$D/W^{\frac{1}{3}} = 0.088$




CHARGE BELOW BOTTOM (Z=-4.0D)




CHARGE AT BOTTOM (Z=-1.0 D)




CRATER DIMENSIONS

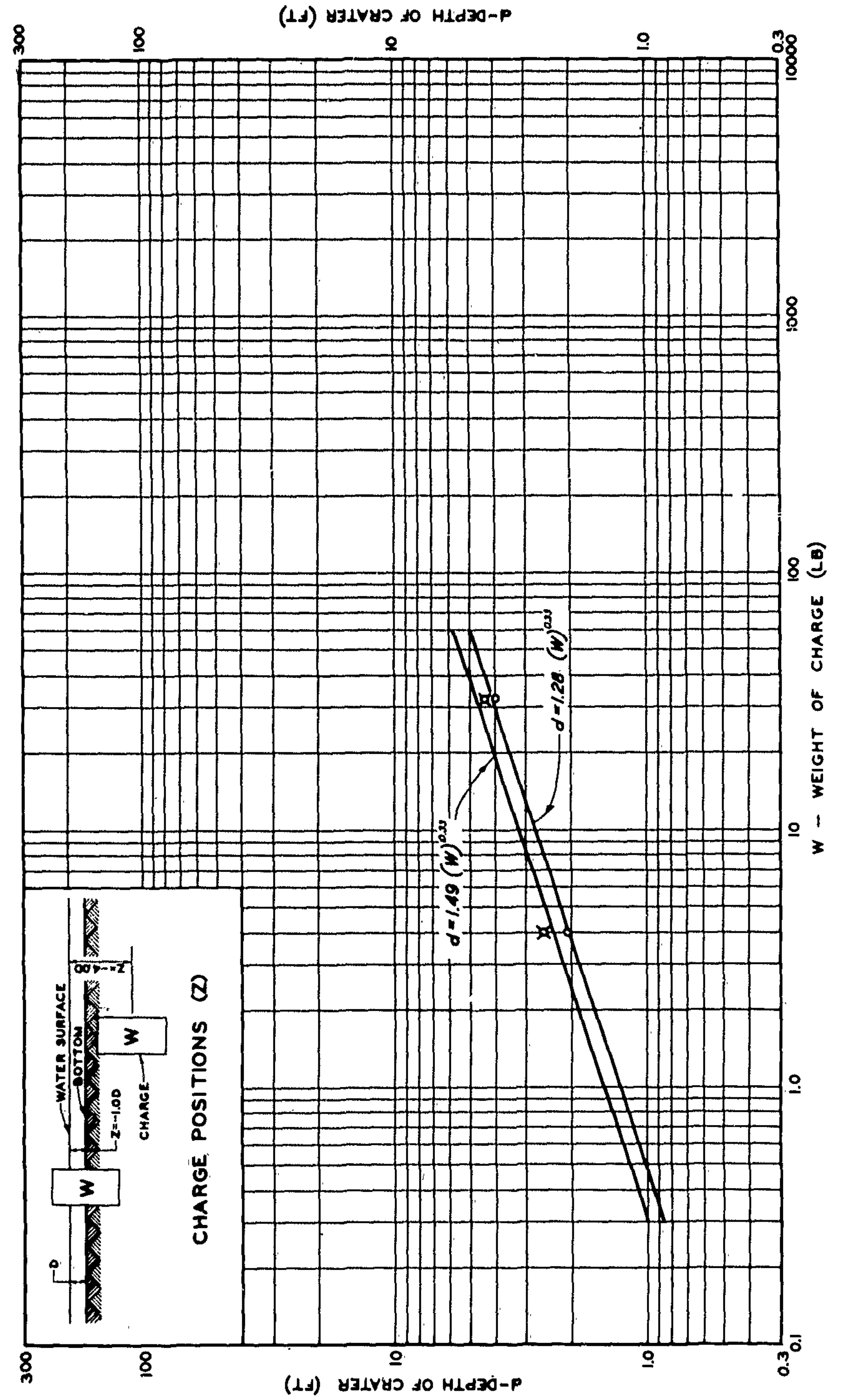
## HALF-CRATER PROFILES

SORRENTO CLAY

CHARGE WEIGHT - 32 LB

$D/W^{\frac{1}{3}} = 0.088$

PLATE 6

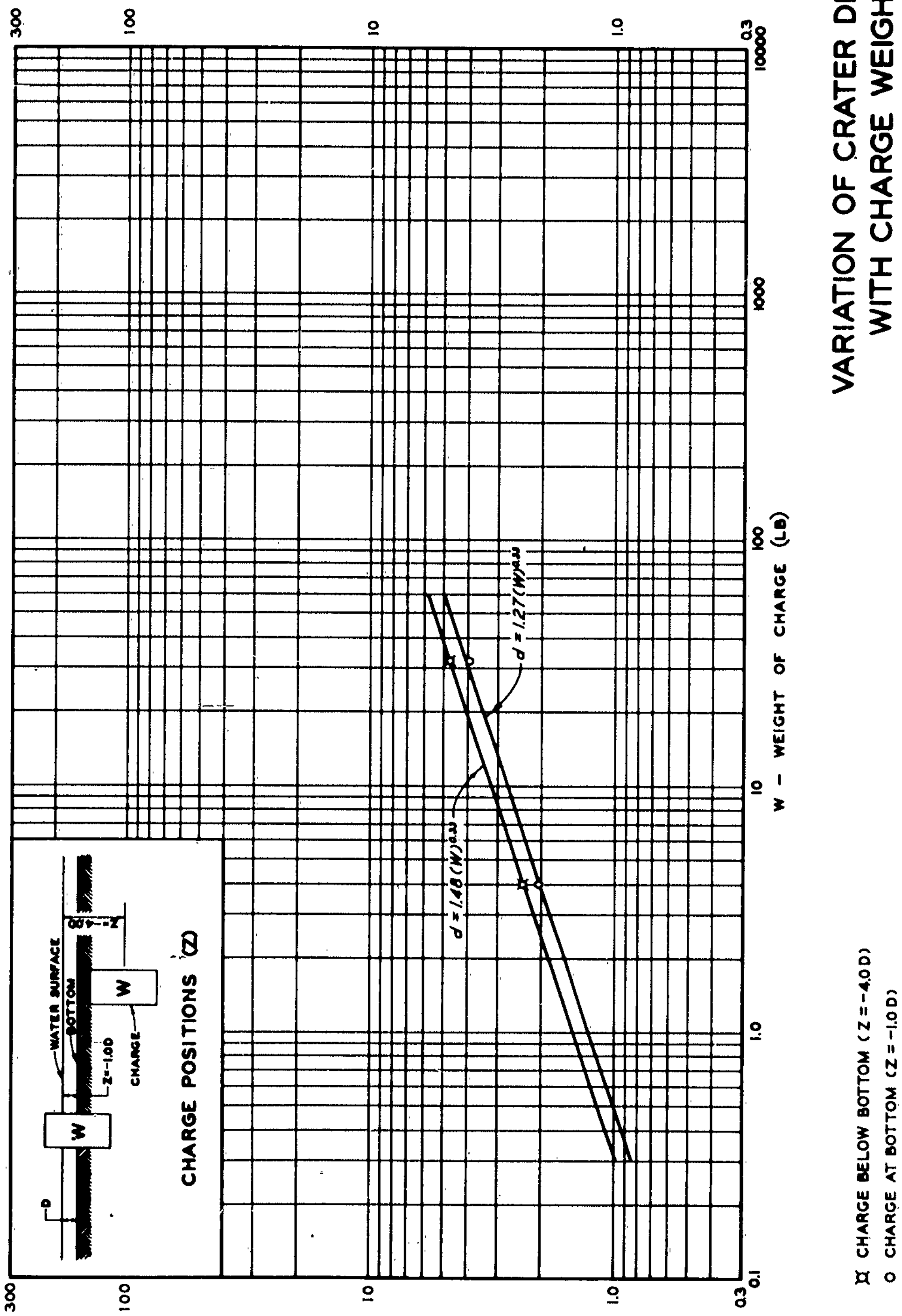



VARIATION OF CRATER DEPTH WITH CHARGE WEIGHT

DIAMOND POINT CLAY

$D/W^{\frac{1}{3}} = 0.088$

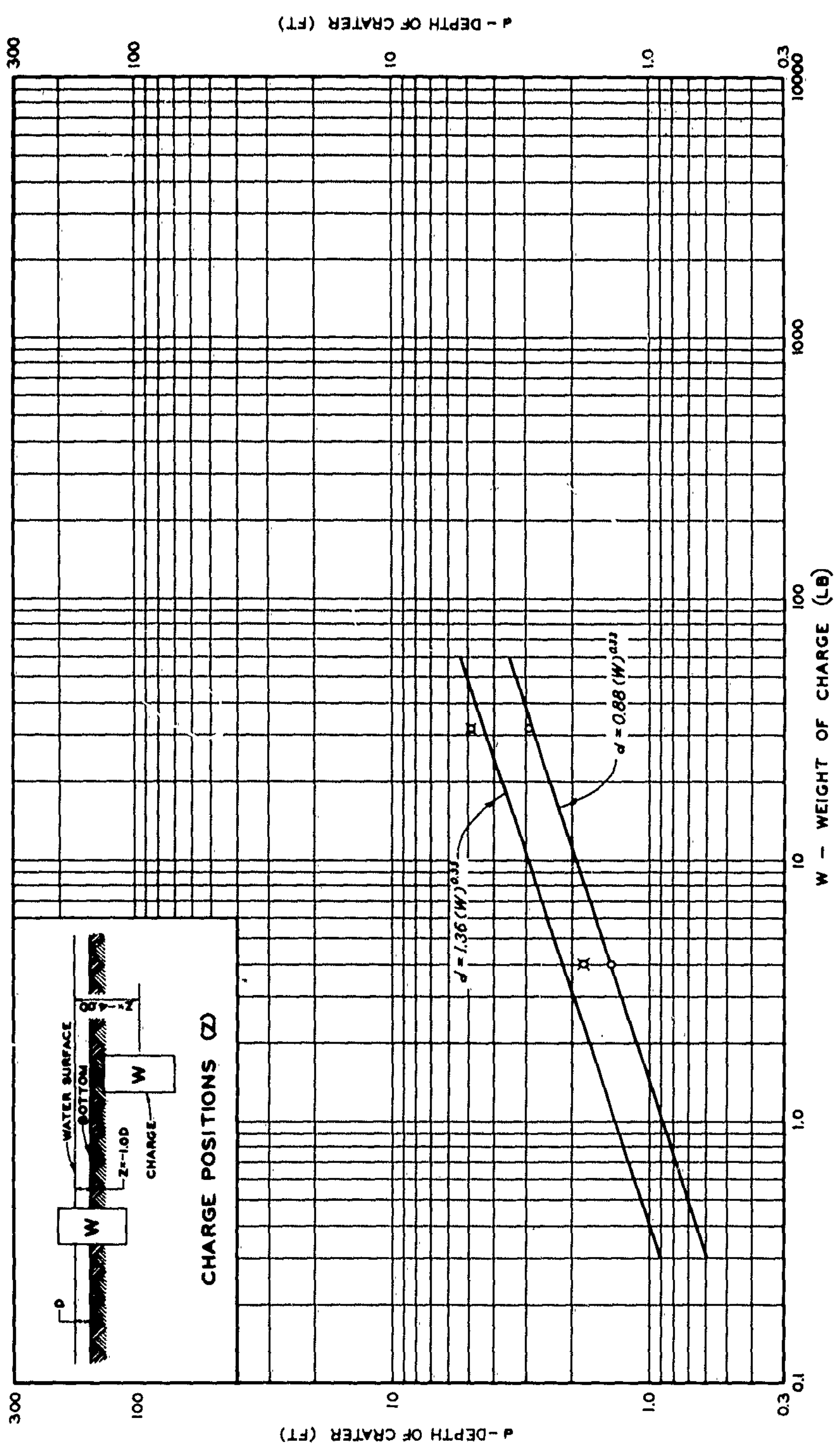
⌧ CHARGE BELOW BOTTOM (Z=-4.0 D)
O CHARGE AT BOTTOM (Z=-1.0 D)




VARIATION OF CRATER DEPTH WITH CHARGE WEIGHT

DELTA POINT CLAY

$D/W^{\frac{1}{3}} = 0.088$

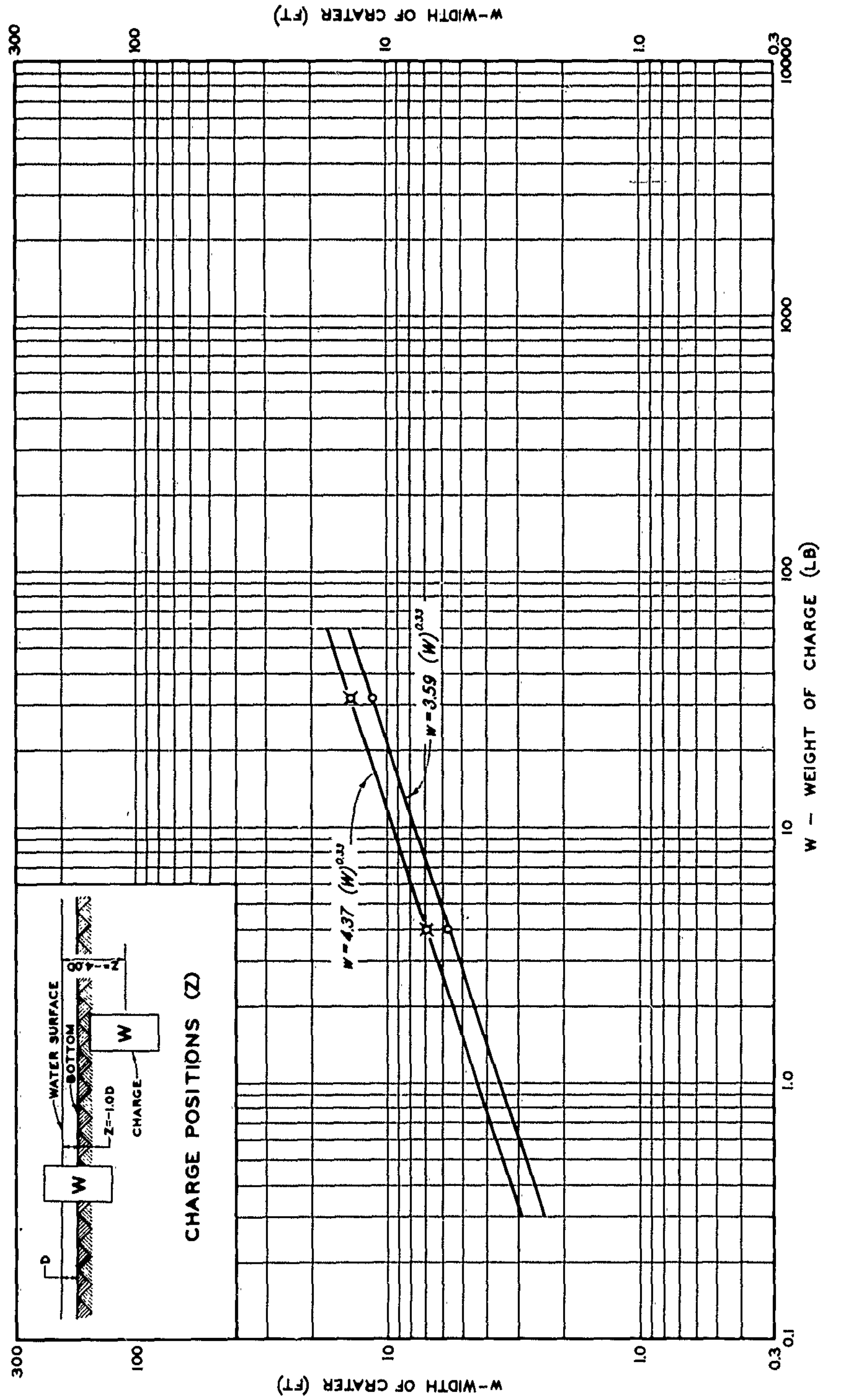



VARIATION OF CRATER DEPTH WITH CHARGE WEIGHT

SORRENTO CLAY

$D/W^{\frac{1}{3}} = 0.088$

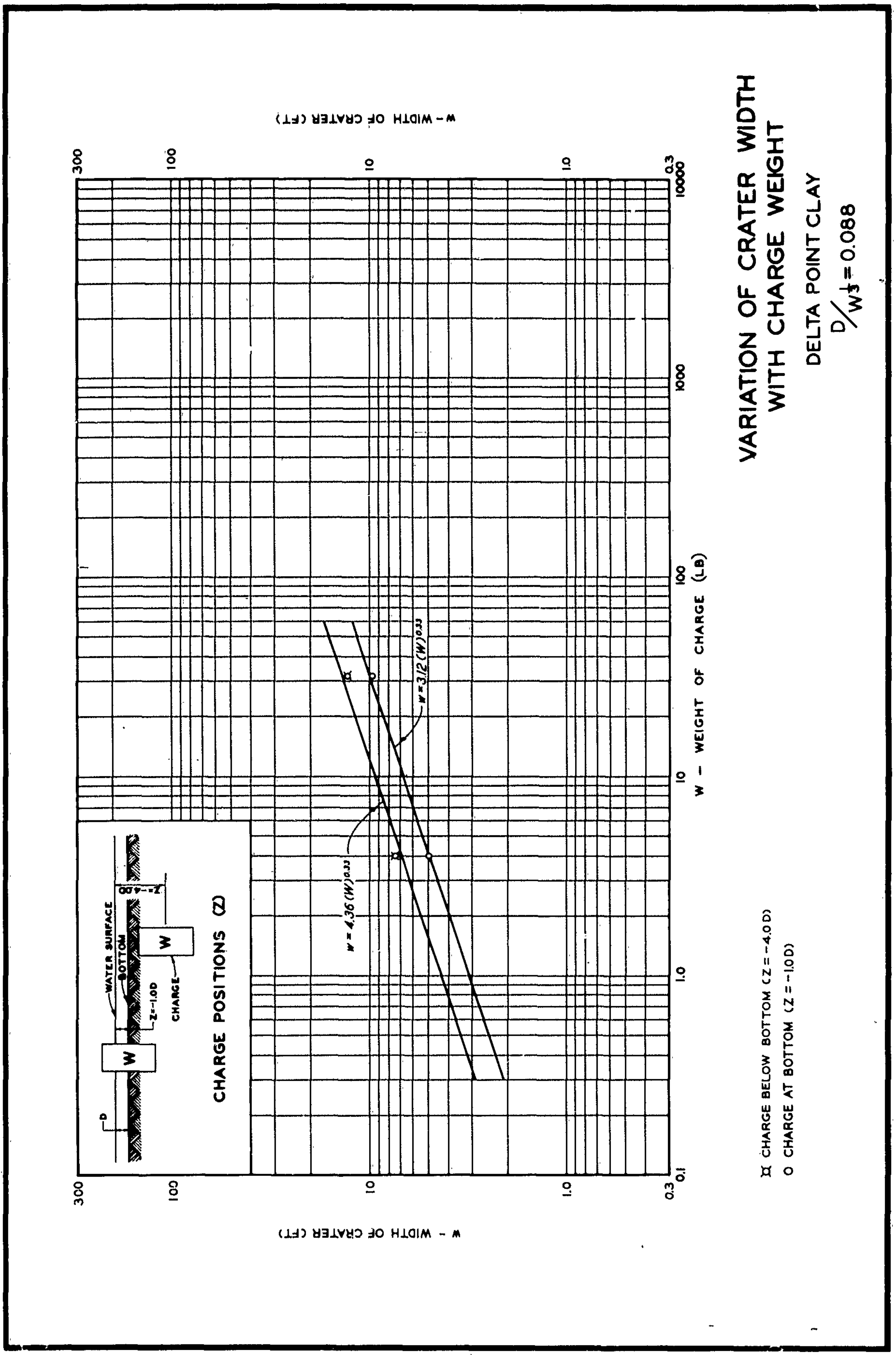
¤ CHARGE BELOW BOTTOM (Z = -4.0D)
o CHARGE AT BOTTOM (Z = -1.0D)




VARIATION OF CRATER WIDTH
WITH CHARGE WEIGHT
DIAMOND POINT CLAY
$D/W^{\frac{1}{3}} = 0.088$

¤ CHARGE BELOW BOTTOM (Z=-4.0 D)
o CHARGE AT BOTTOM (Z=-1.0 D)

PLATE 10




VARIATION OF CRATER WIDTH WITH CHARGE WEIGHT

DELTA POINT CLAY

$D/W^{1/3} = 0.088$

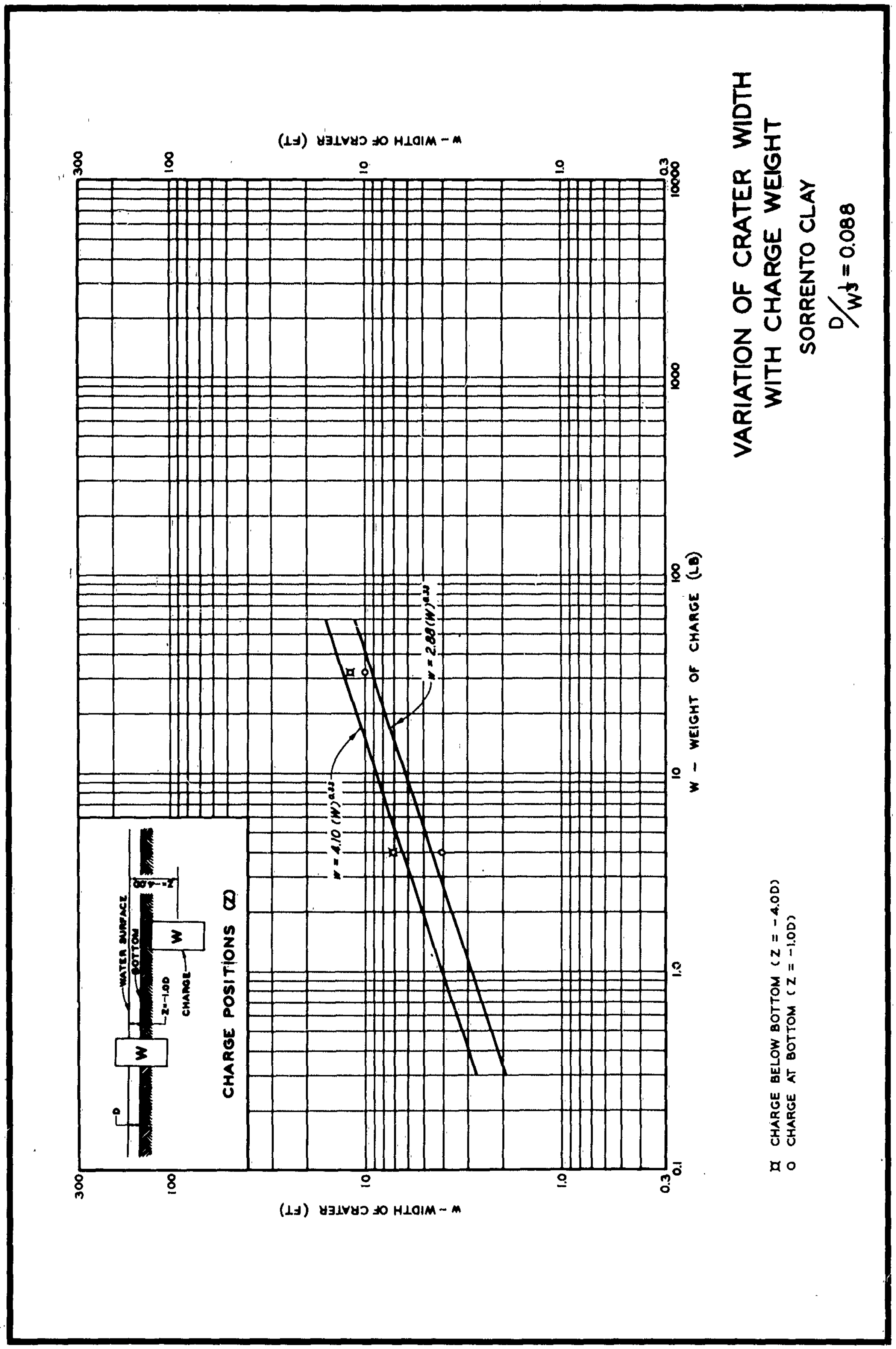
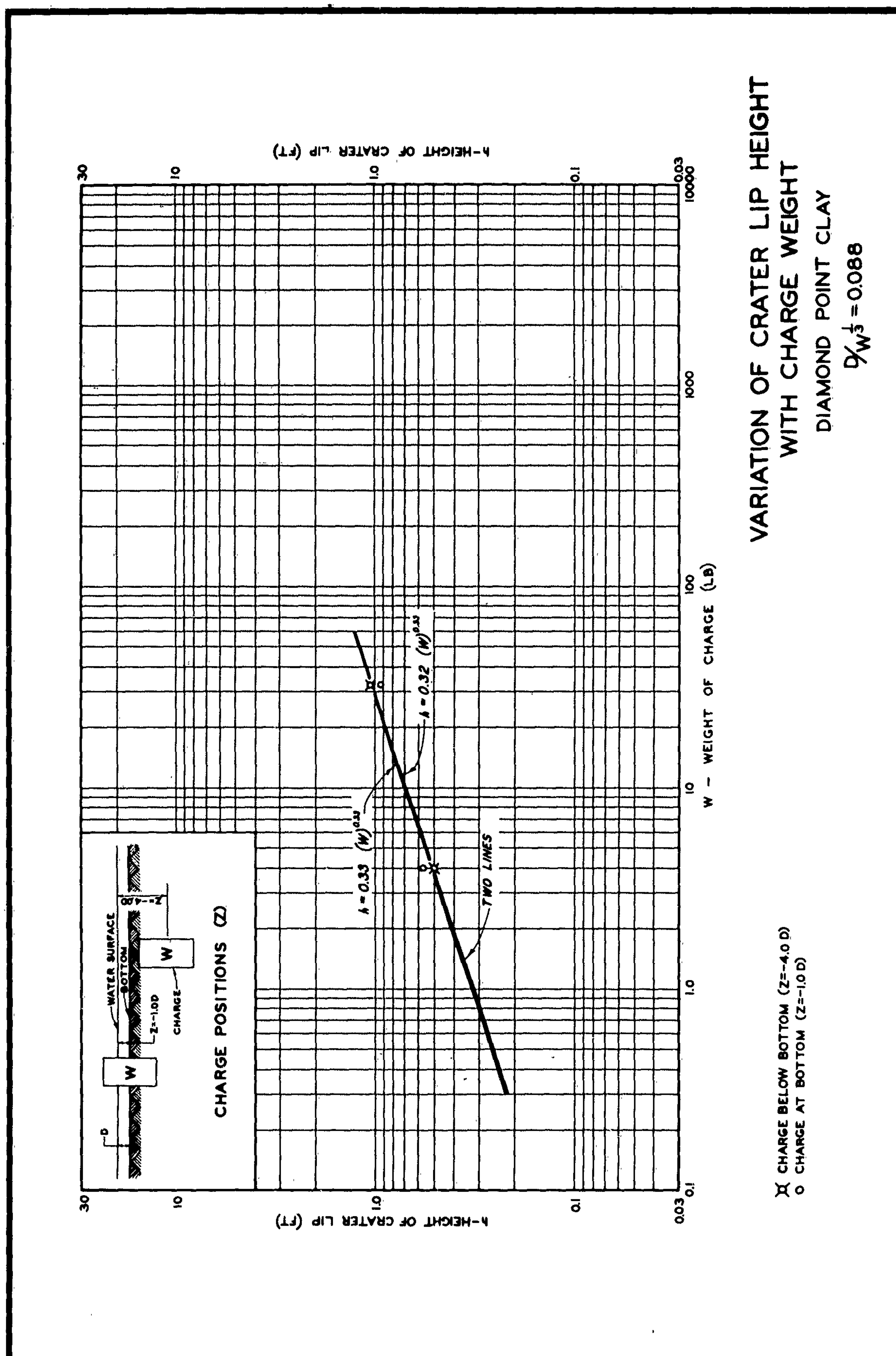
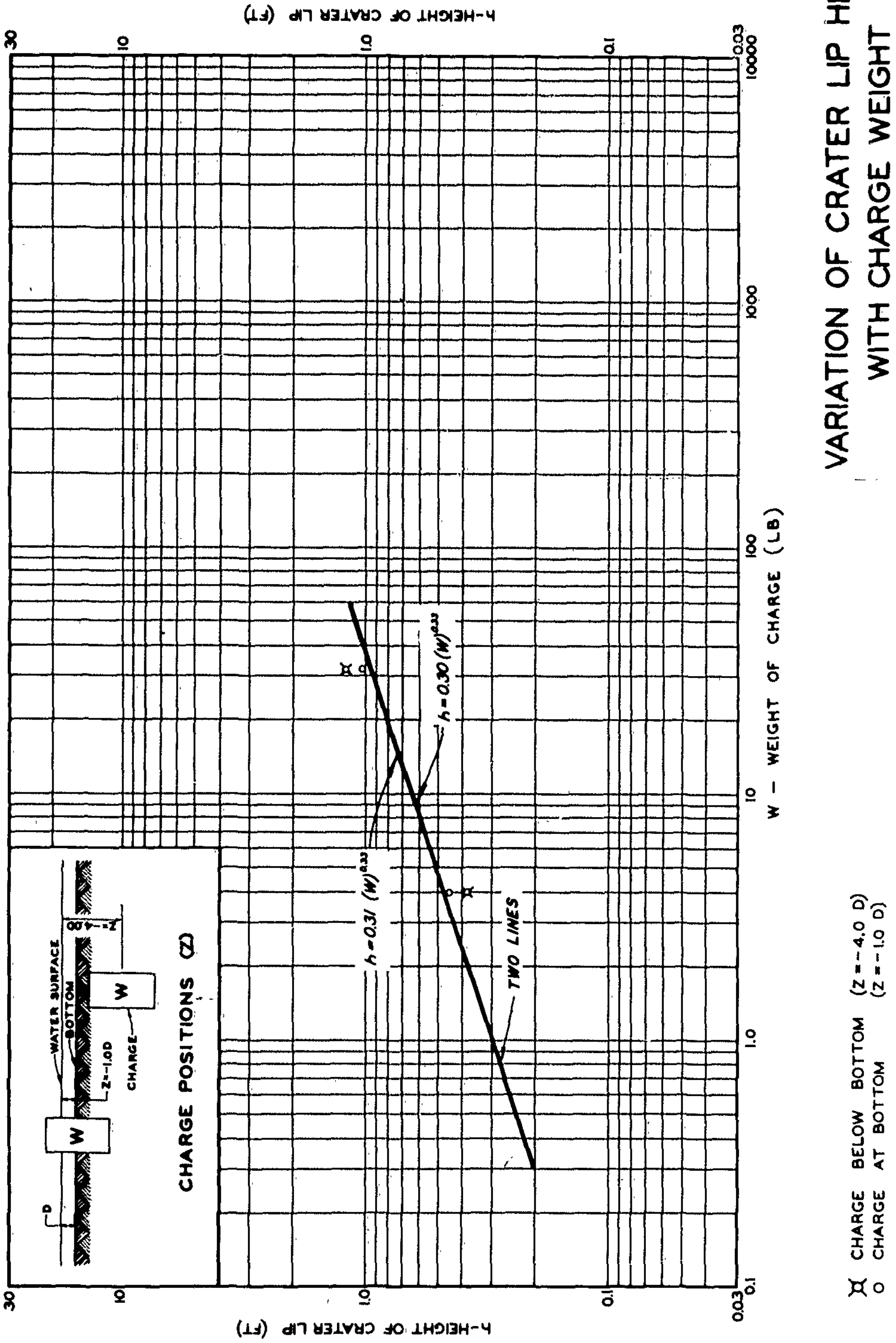

VARIATION OF CRATER WIDTH
WITH CHARGE WEIGHT
SORRENTO CLAY
$D/W^{1/3} = 0.088$
W - WEIGHT OF CHARGE (LB)
w - WIDTH OF CRATER (FT)
w = 4.10 (W)
w = 2.88 (W)
CHARGE POSITIONS (Z)
WATER SURFACE
BOTTOM
CHARGE
Z=-1.0D
Z=-4.0D
D
W
CHARGE BELOW BOTTOM (Z = -4.0D)
CHARGE AT BOTTOM (Z = -1.0D)

PLATE 12


VARIATION OF CRATER LIP HEIGHT
WITH CHARGE WEIGHT
DIAMOND POINT CLAY
D/W^(1/3) = 0.088
h-HEIGHT OF CRATER LIP (FT)
W - WEIGHT OF CHARGE (LB)
30
10
1.0
0.1
0.03
0.1
1.0
10
100
1000
10000
h = 0.33 (W)^0.33
h = 0.32 (W)^0.33
TWO LINES
WATER SURFACE
BOTTOM
D
Z=-1.0D
Z=-4.0D
CHARGE
W
CHARGE POSITIONS (Z)
CHARGE BELOW BOTTOM (Z=-4.0 D)
o CHARGE AT BOTTOM (Z=-1.0 D)




VARIATION OF CRATER LIP HEIGHT WITH CHARGE WEIGHT
DELTA POINT CLAY
$D/W^{\frac{1}{3}}$ 0.088

PLATE 14

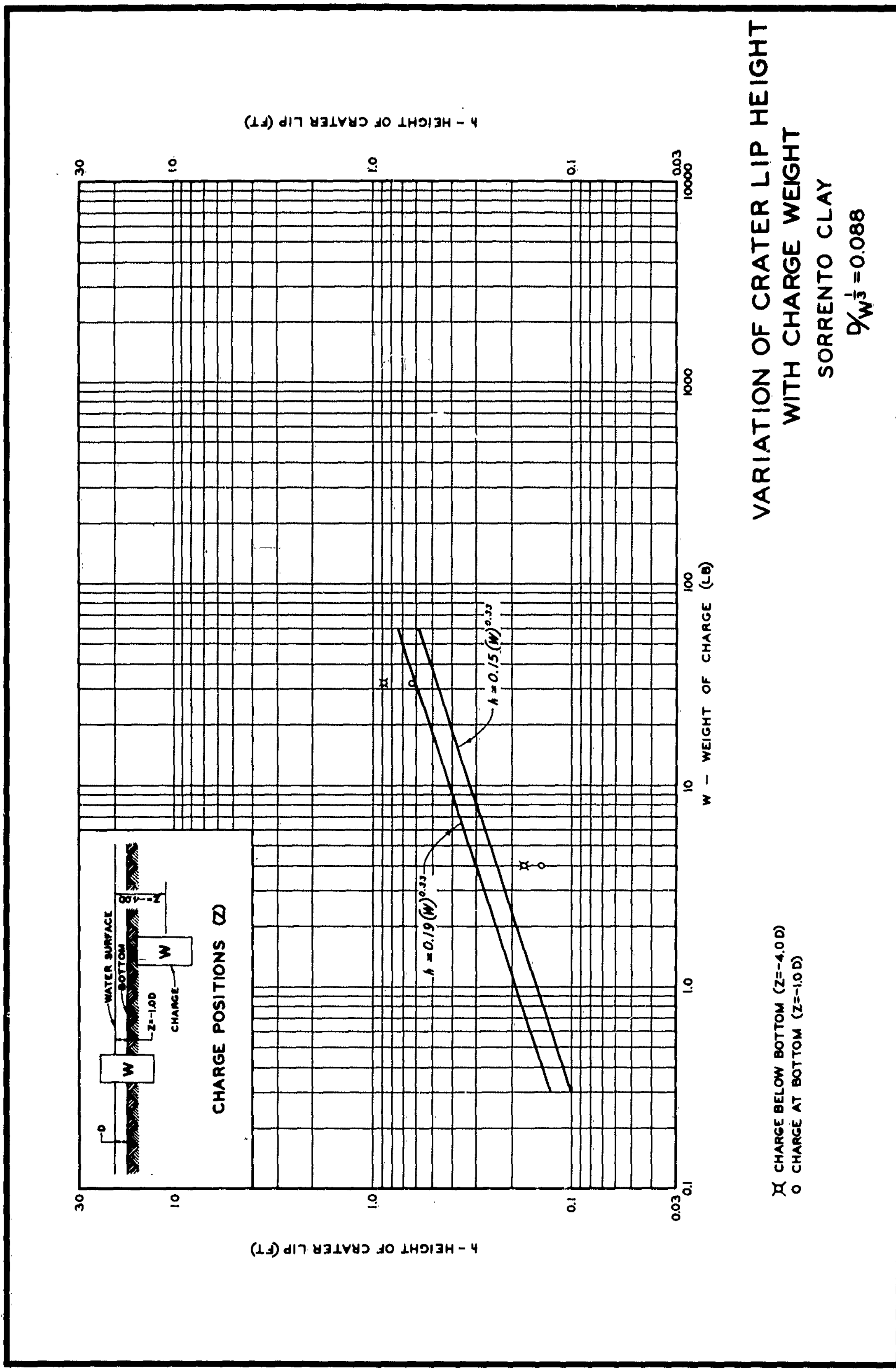
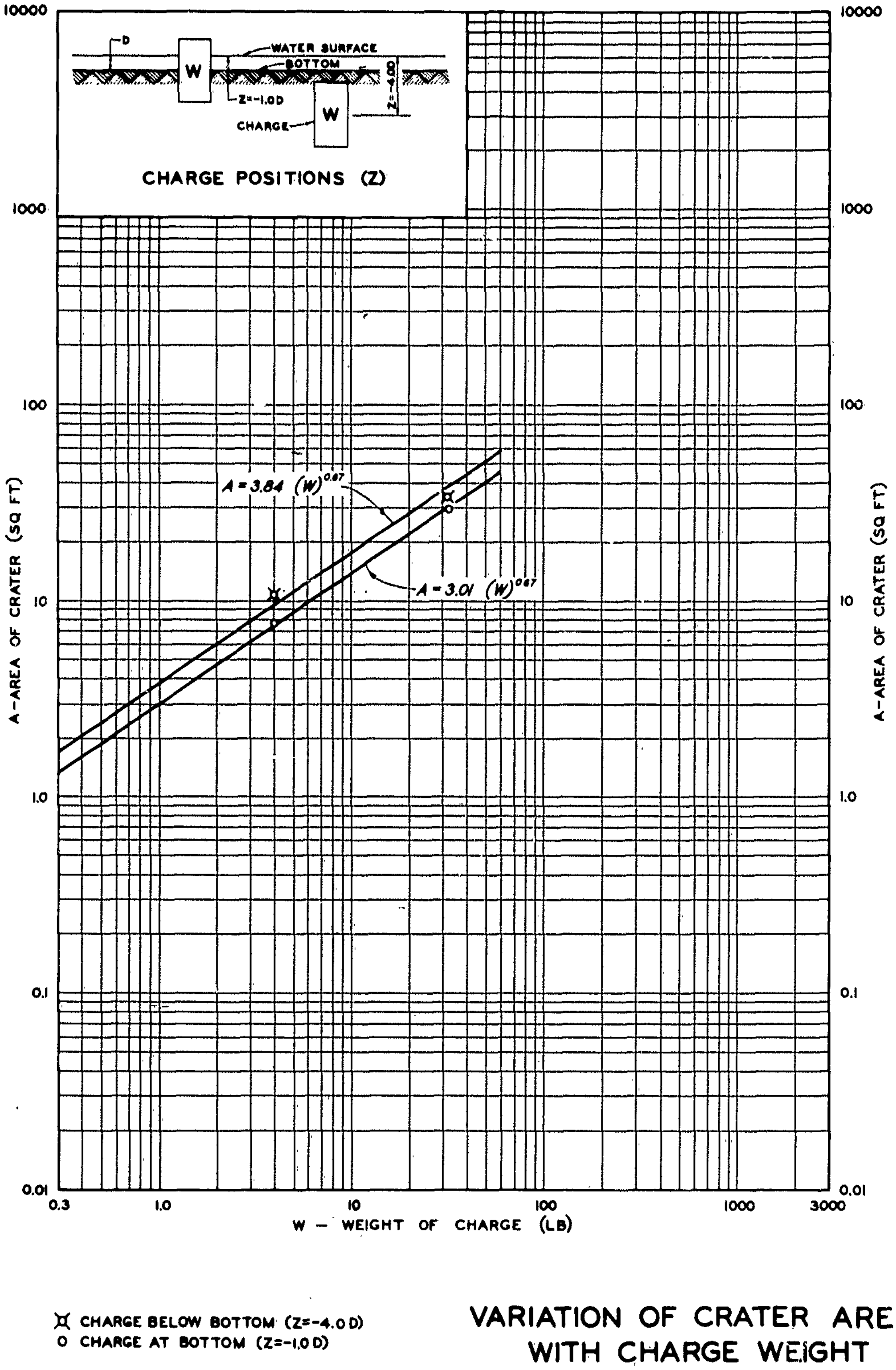
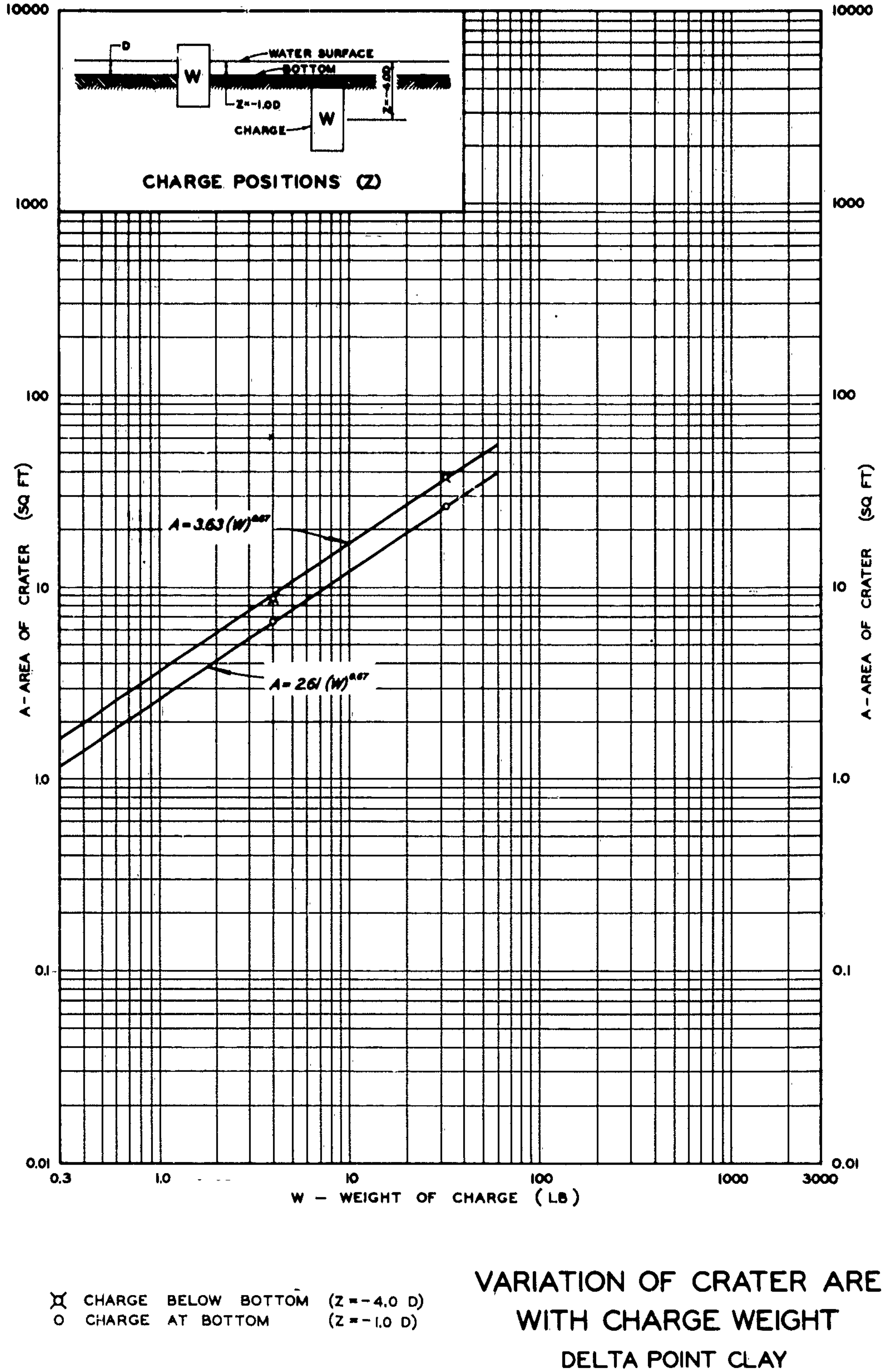

VARIATION OF CRATER LIP HEIGHT
WITH CHARGE WEIGHT
SORRENTO CLAY
$D/W^{\frac{1}{3}} = 0.088$
h - HEIGHT OF CRATER LIP (FT)
W - WEIGHT OF CHARGE (LB)
$h = 0.15(W)^{0.33}$
$h = 0.19(W)^{0.33}$
CHARGE POSITIONS (Z)
WATER SURFACE
BOTTOM
Z=-1.0D
Z=-4.0D
CHARGE
W
D
CHARGE BELOW BOTTOM (Z=-4.0D)
O CHARGE AT BOTTOM (Z=-1.0D)
30
10
1.0
0.1
0.03
0.1
1.0
10
100
1000
10000

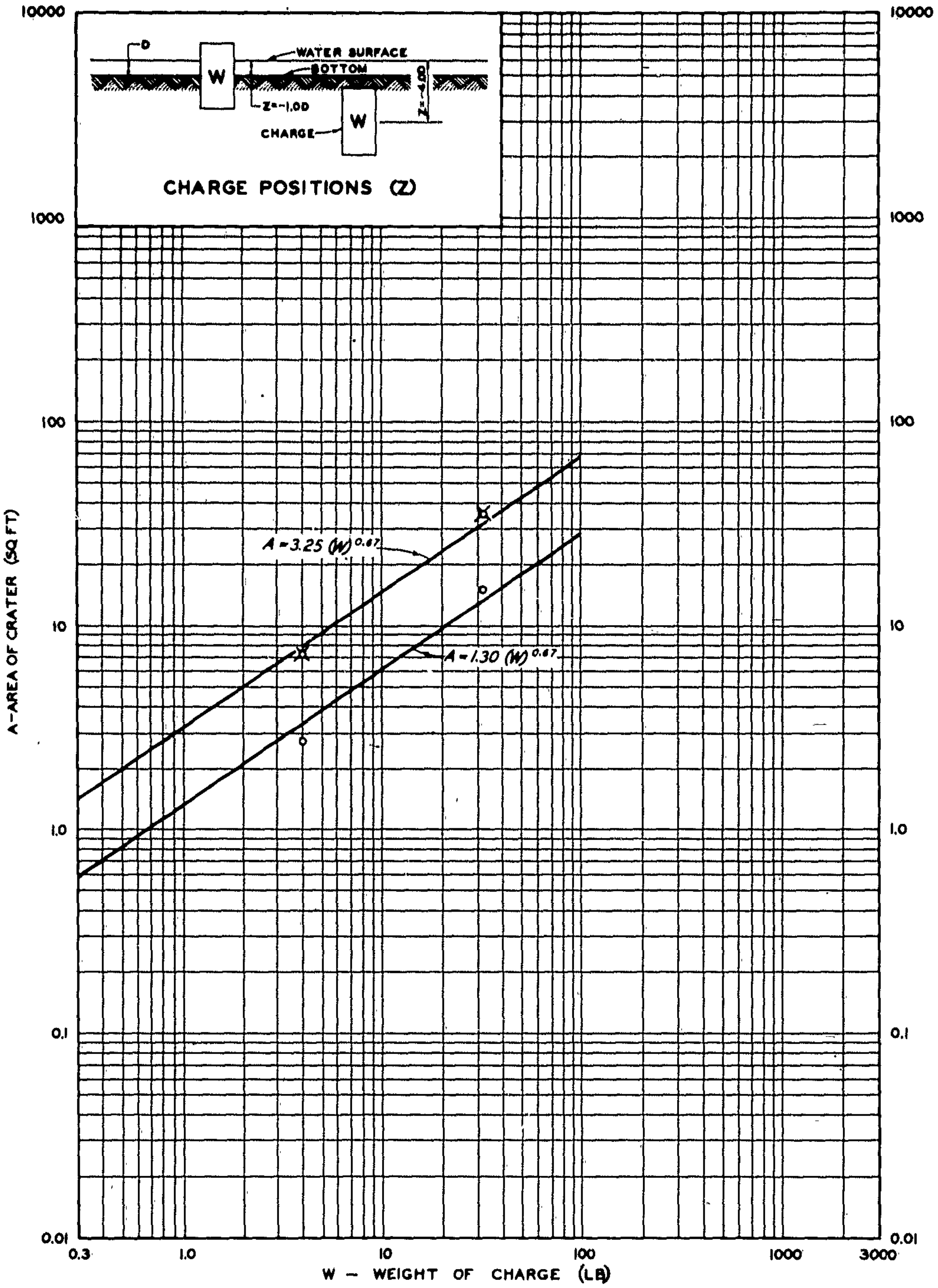
PLATE 15




VARIATION OF CRATER AREA WITH CHARGE WEIGHT
DIAMOND POINT CLAY
$D/W^{\frac{1}{3}} = 0.088$



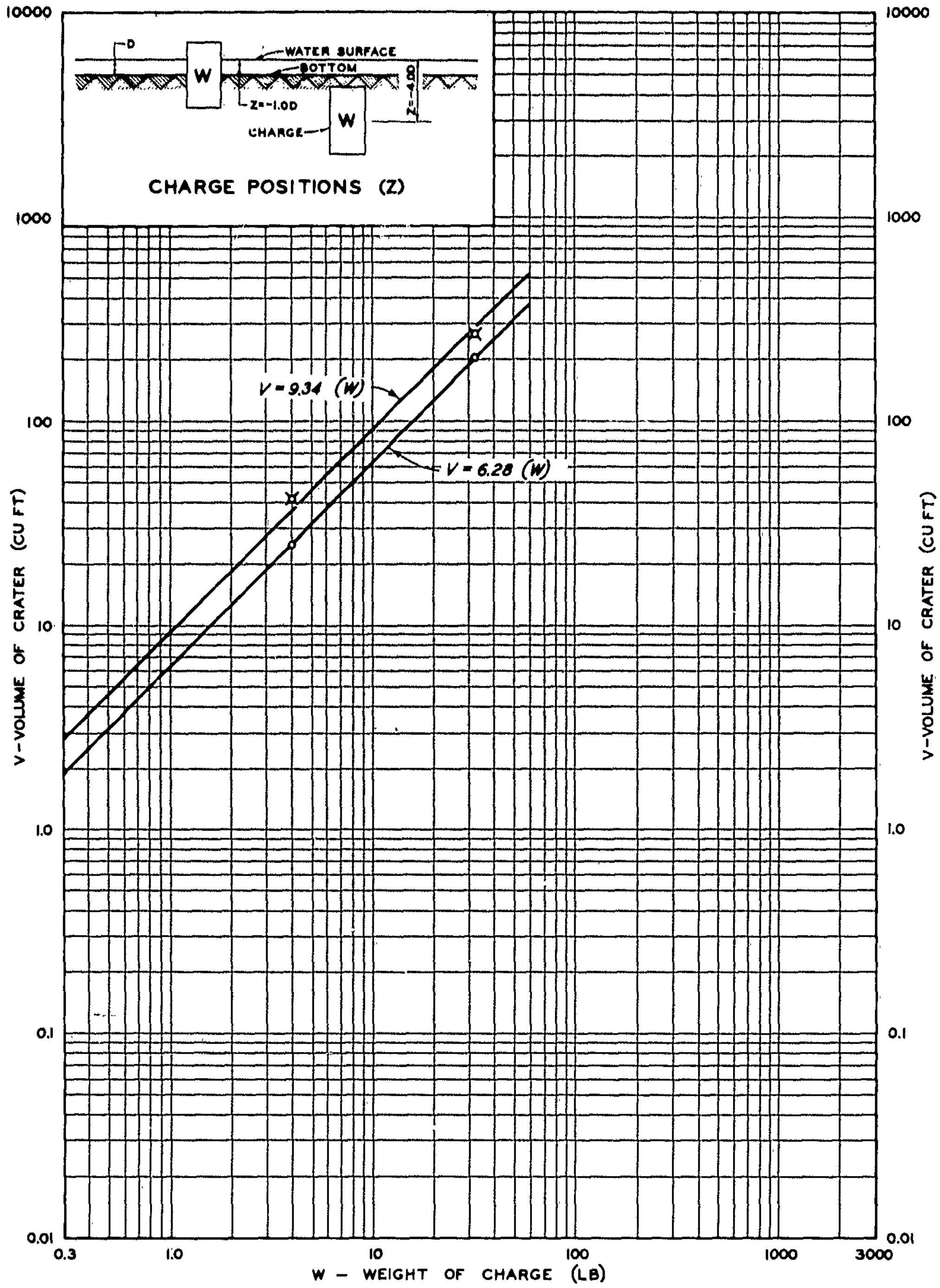

VARIATION OF CRATER AREA
WITH CHARGE WEIGHT
DELTA POINT CLAY
$D/W^{\frac{1}{3}}$ 0.088




VARIATION OF CRATER AREA WITH CHARGE WEIGHT

SORRENTO CLAY

$D/W^{\frac{1}{3}} = 0.088$

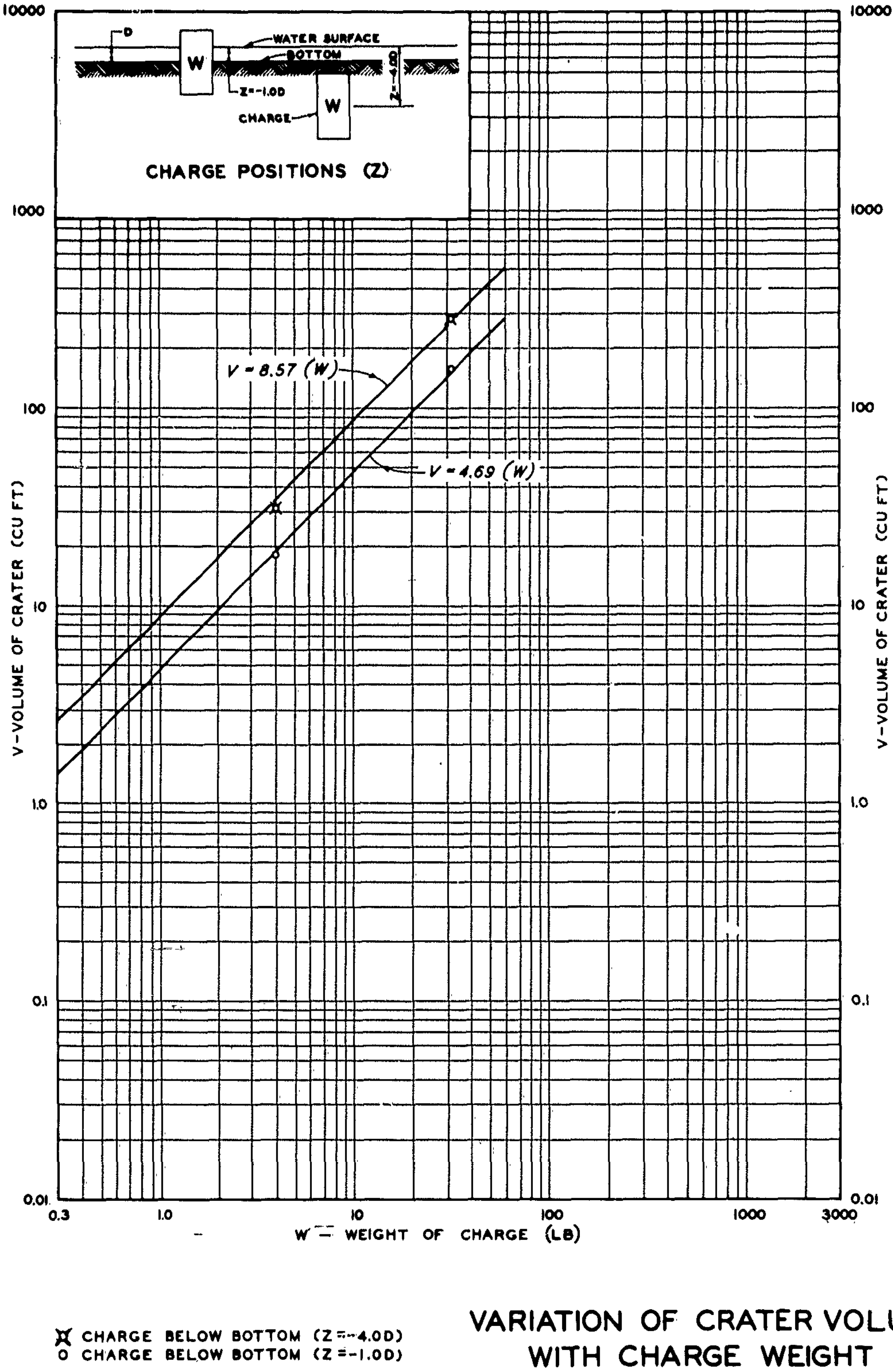



⌧ CHARGE BELOW BOTTOM (Z=-4.0 D)
O CHARGE AT BOTTOM (Z=-1.0 D)

VARIATION OF CRATER VOLUME
WITH CHARGE WEIGHT

DIAMOND POINT CLAY

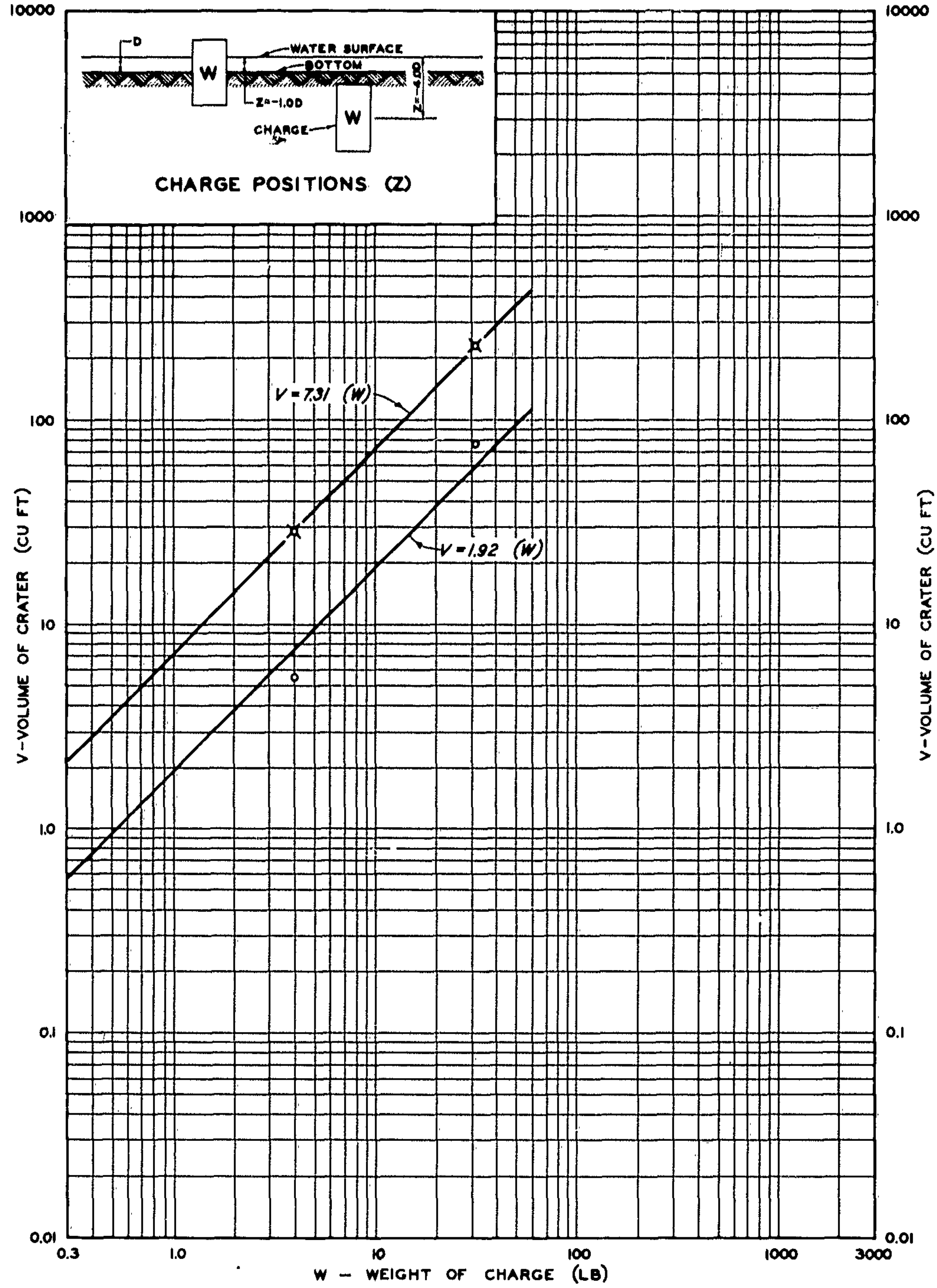
$D/W^{\frac{1}{3}} = 0.088$




VARIATION OF CRATER VOLUME WITH CHARGE WEIGHT

DELTA POINT CLAY

$D/W^{\frac{1}{3}} = 0.088$

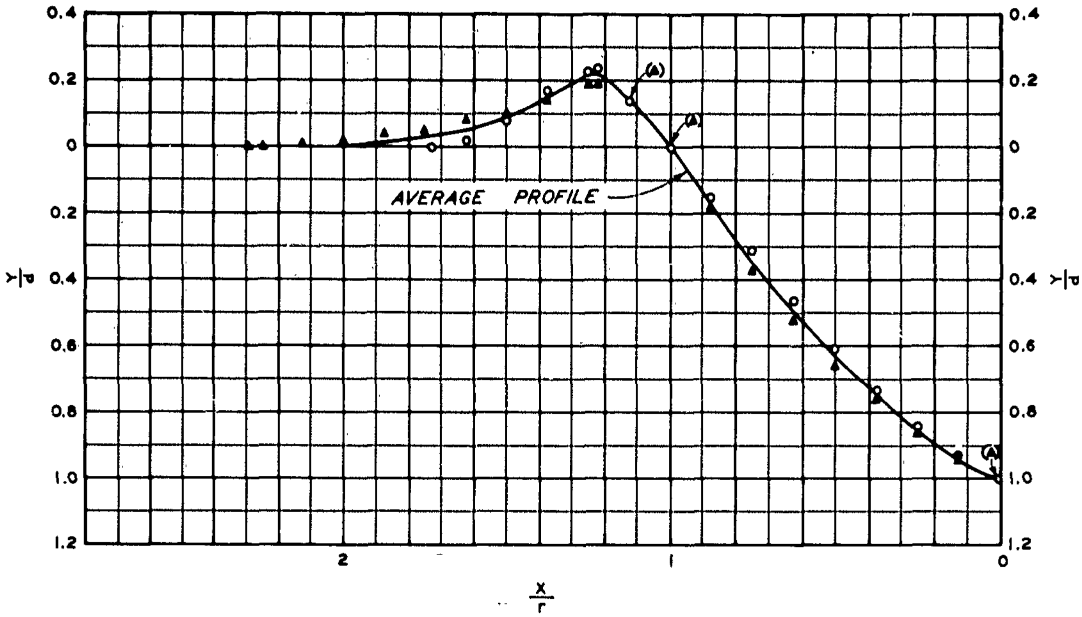



¤ CHARGE BELOW BOTTOM (Z=-4.0 D)
o CHARGE AT BOTTOM (Z=-1.0 D)

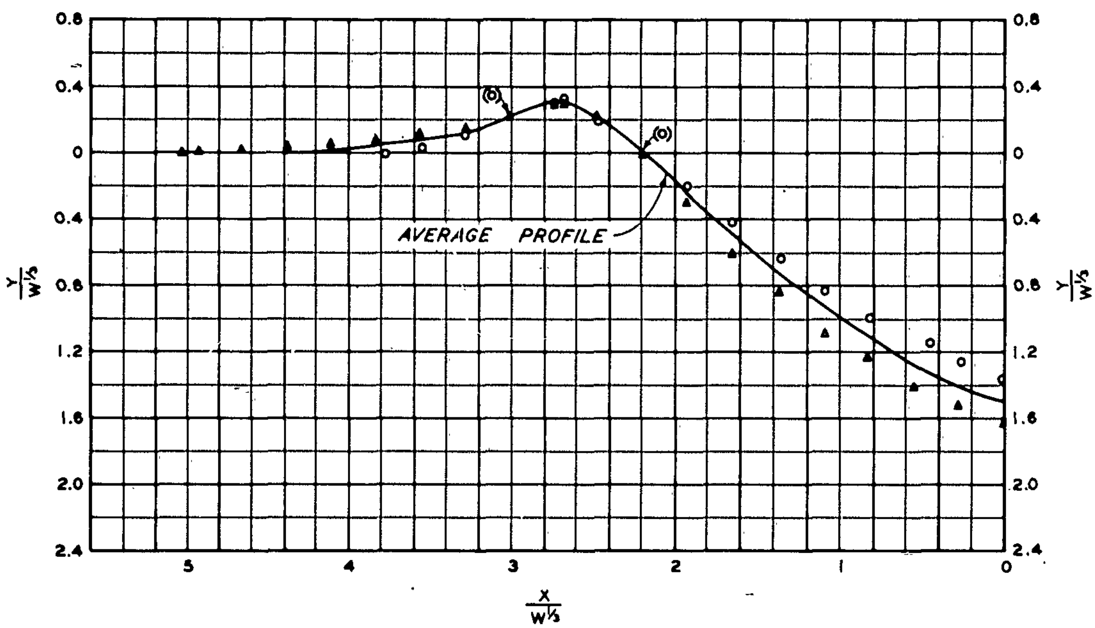
VARIATION OF CRATER VOLUME WITH CHARGE WEIGHT

SORRENTO CLAY

$D/W^{\frac{1}{3}} = 0.088$




X/r vs Y/d



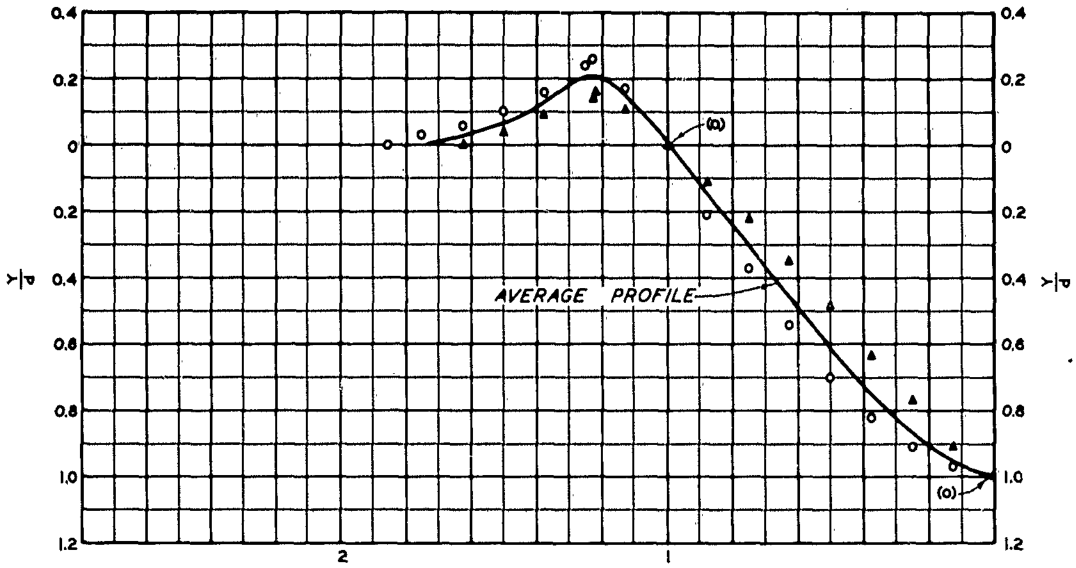

$\frac{X}{W^{1/3}}$ vs $\frac{Y}{W^{1/3}}$

O 32-LB CHARGE
Δ 4-LB CHARGE

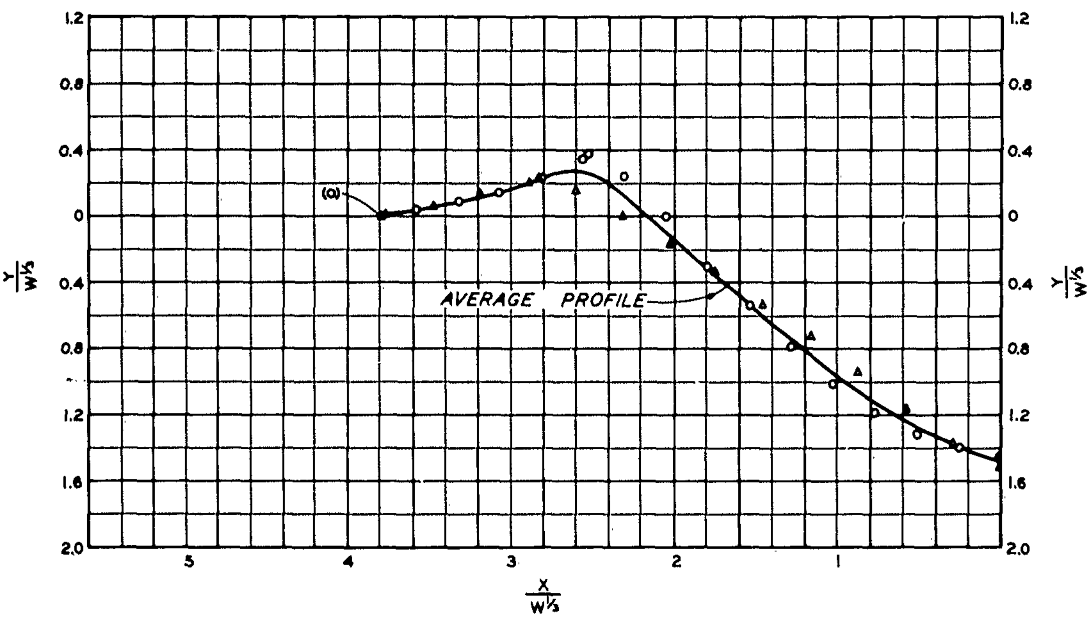
## DIMENSIONLESS PLOTS OF HALF-CRATER PROFILES

DIAMOND POINT CLAY
CHARGE BELOW BOTTOM (Z=-4.0 D)

$D/W^{1/3} = 0.088$



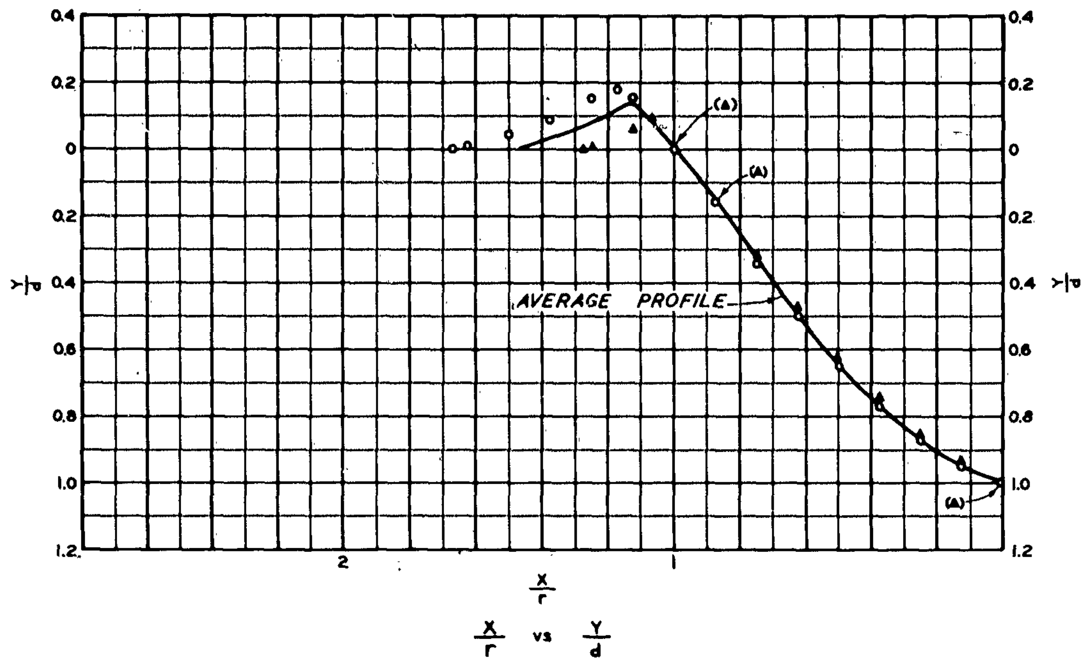

X/r vs Y/d

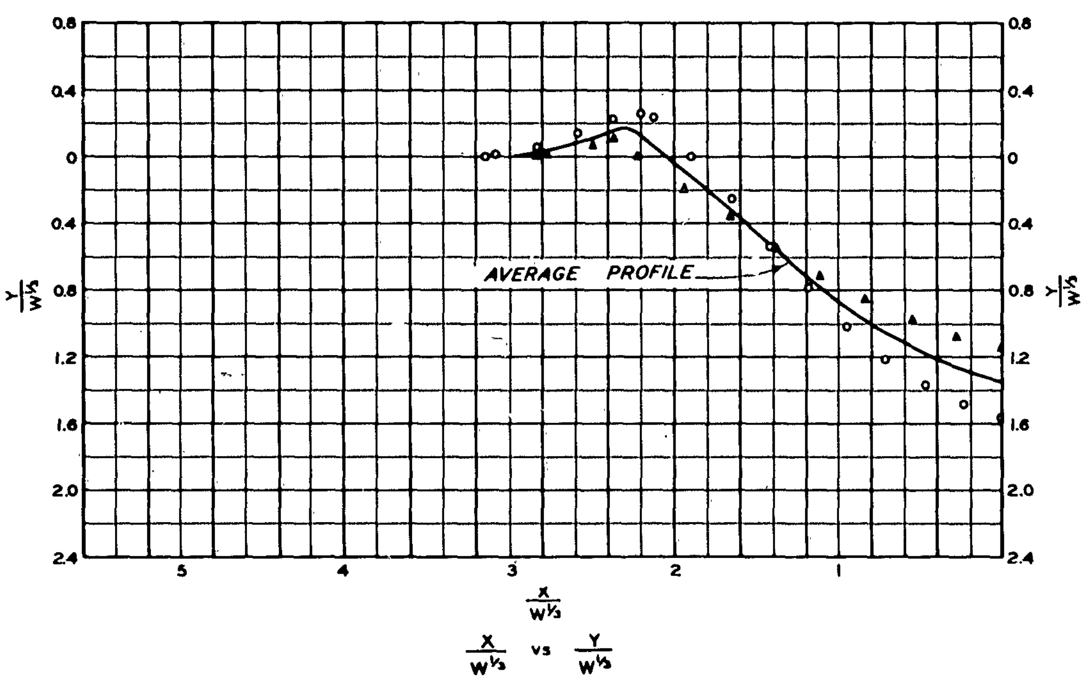



$\frac{X}{W^{1/3}}$ vs $\frac{Y}{W^{1/3}}$

O 32-LB CHARGE
Δ 4-LB CHARGE

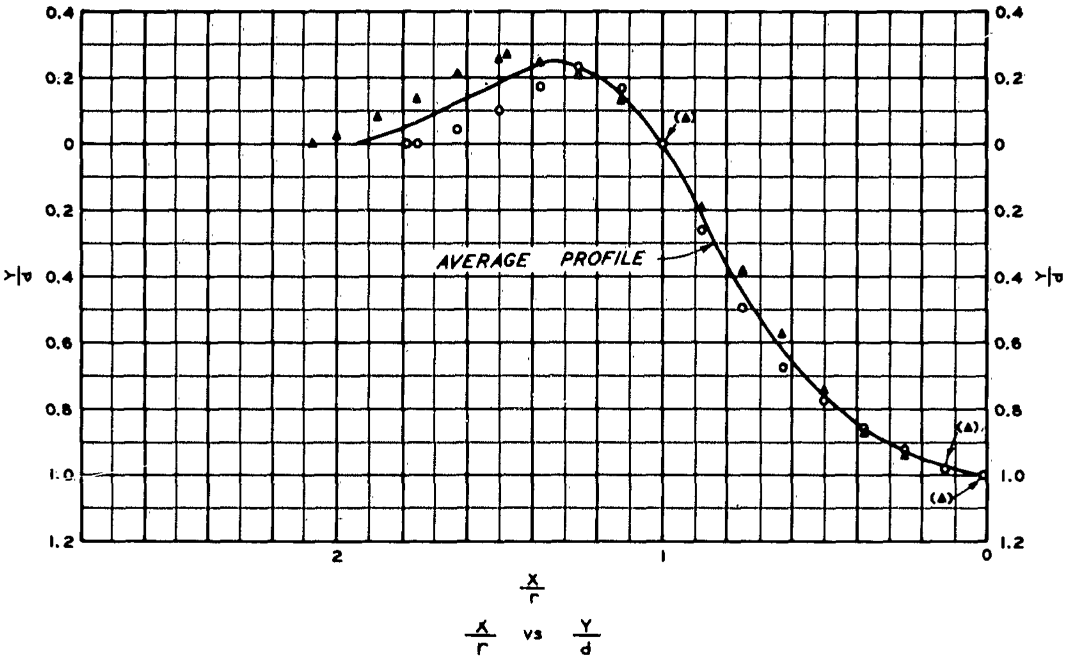
DIMENSIONLESS PLOTS OF HALF-CRATER PROFILES
DELTA POINT CLAY
CHARGE BELOW BOTTOM (Z = −4.0 D)
$D/W^{\frac{1}{3}} = 0.088$

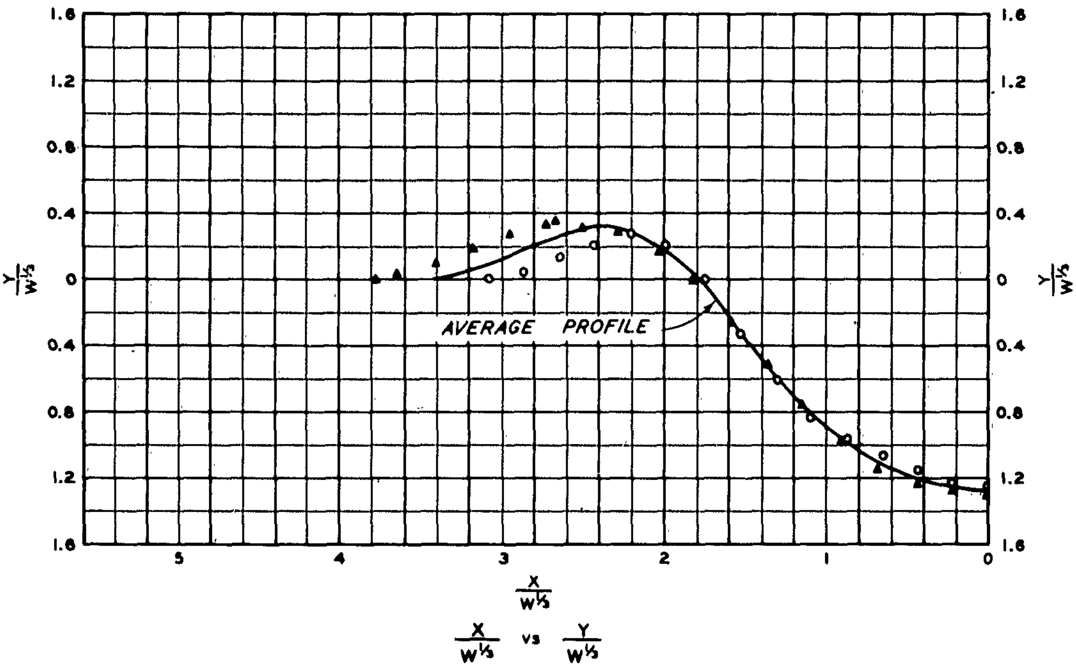



O 32-LB CHARGE
Δ 4-LB CHARGE

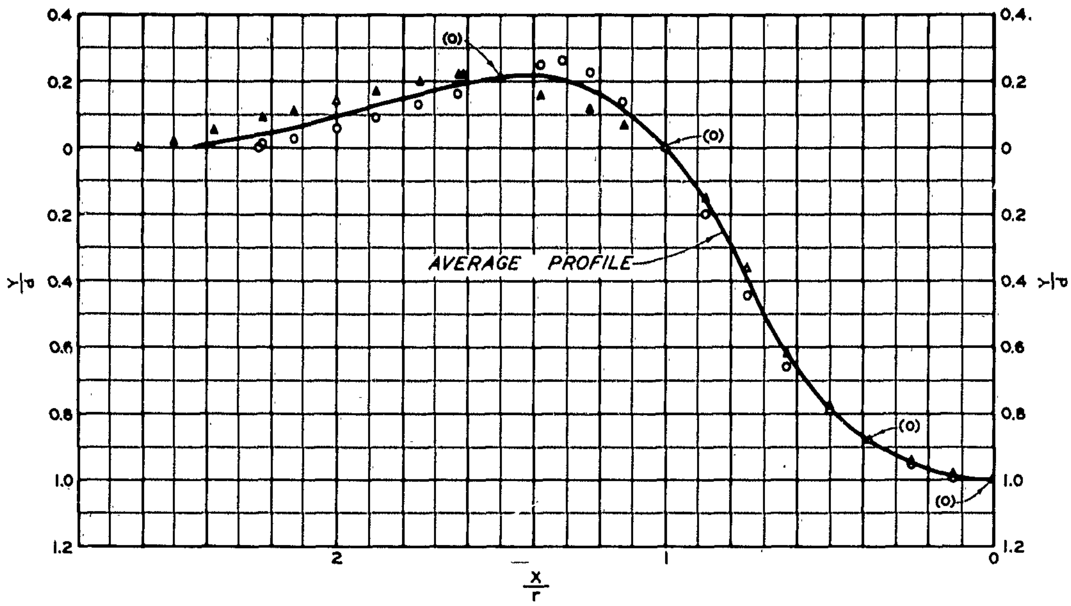
DIMENSIONLESS PLOTS OF HALF-CRATER PROFILES
SORRENTO CLAY
CHARGE BELOW BOTTOM (Z = −4.0 D)
$D/W^{\frac{1}{3}} = 0.088$



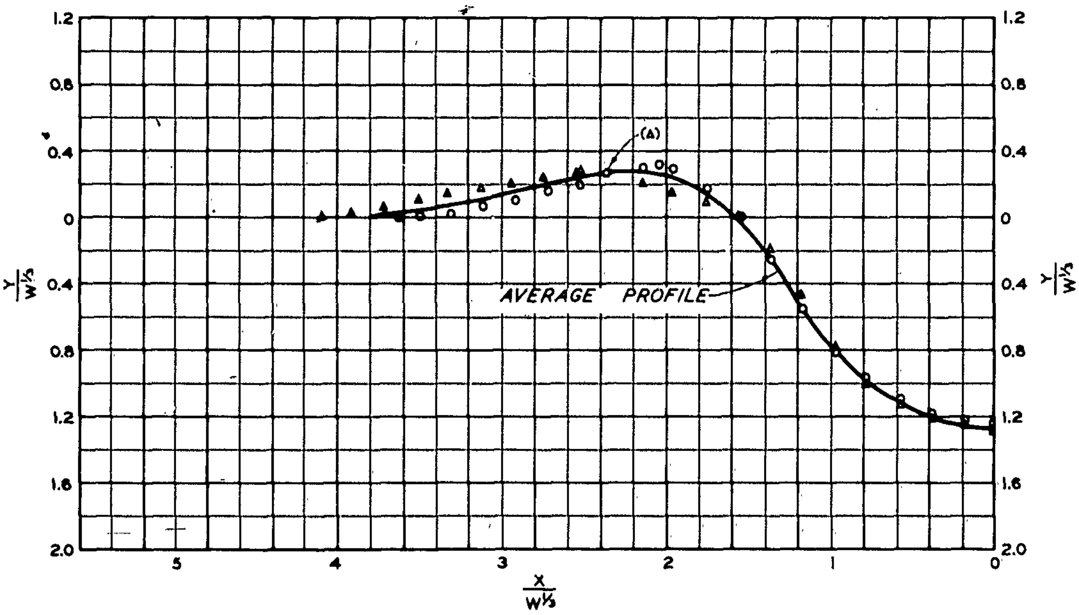




O 32-LB CHARGE
Δ 4-LB CHARGE

DIMENSIONLESS PLOTS OF HALF-CRATER PROFILES
DIAMOND POINT CLAY
CHARGE AT BOTTOM (Z = −1.0 D)
$D/W^{\frac{1}{3}} = 0.088$



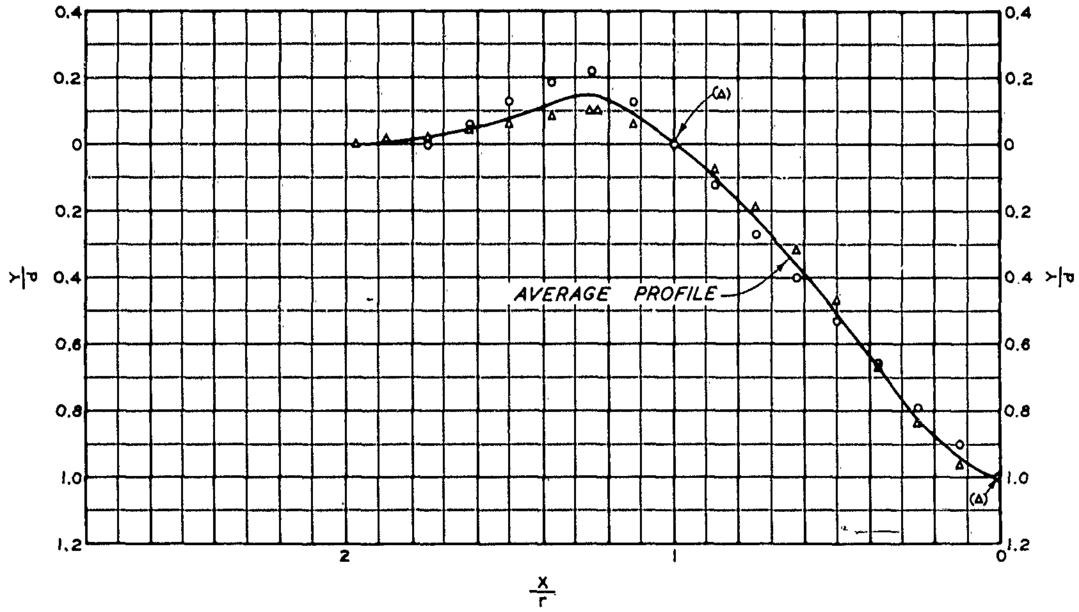

$\frac{X}{r}$ vs $\frac{Y}{d}$



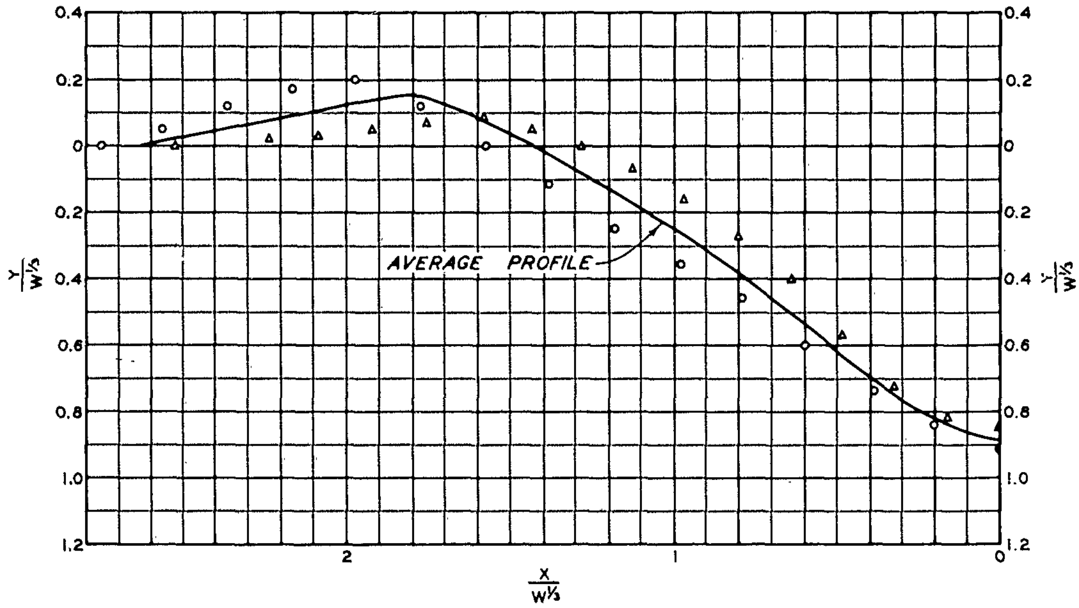

$\frac{X}{W^{1/3}}$ vs $\frac{Y}{W^{1/3}}$

O 32-LB CHARGE
Δ 4-LB CHARGE

DIMENSIONLESS PLOTS OF
HALF-CRATER PROFILES
DELTA POINT CLAY
CHARGE AT BOTTOM (Z=−1.0 D)
$D/W^{\frac{1}{3}} = 0.088$




$\frac{X}{r}$ vs $\frac{Y}{d}$



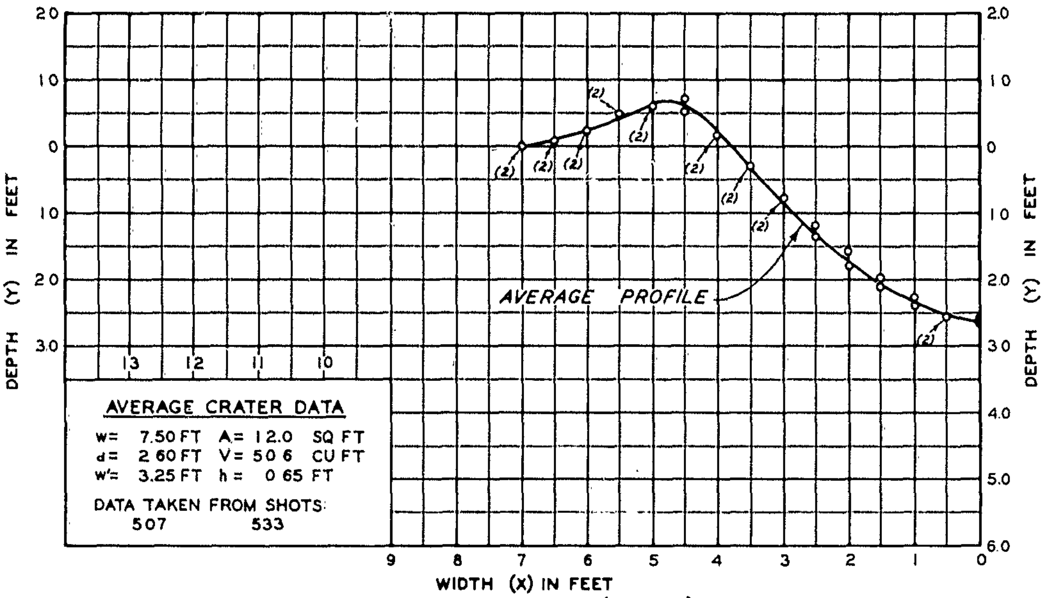

$\frac{X}{W^{1/3}}$ vs $\frac{Y}{W^{1/3}}$

O 32-LB CHARGE
Δ 4-LB CHARGE

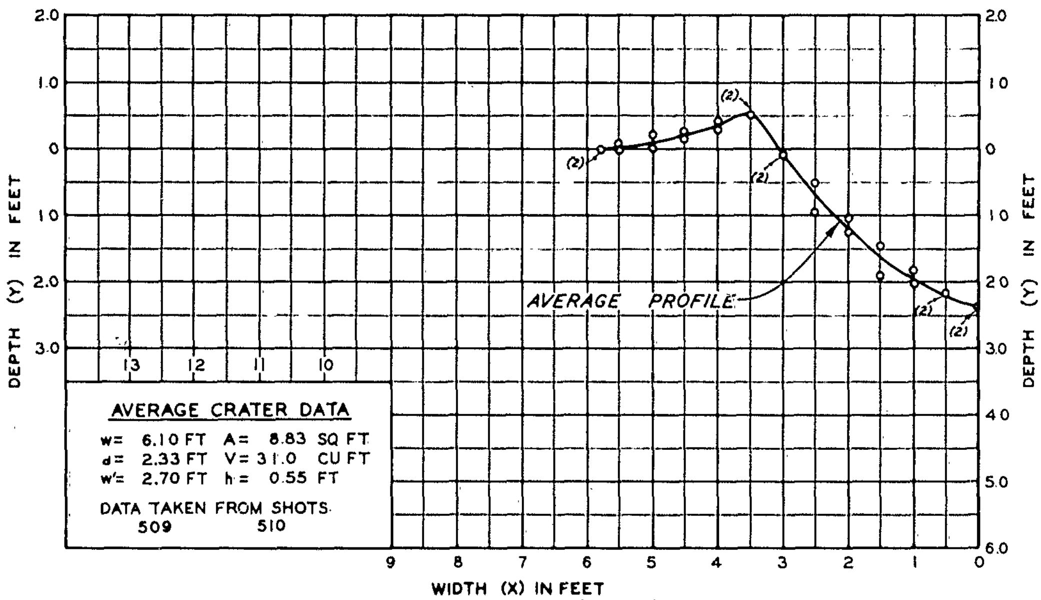
DIMENSIONLESS PLOTS OF
HALF-CRATER PROFILES
SORRENTO CLAY
CHARGE AT BOTTOM (Z=-1.0 D)
$D/W^{\frac{1}{3}} = 0.088$

# PLATES 28 - 36

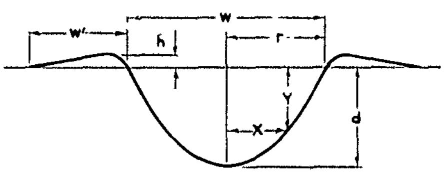
## SCALED WATER DEPTH - 60 FT.




CHARGE BELOW BOTTOM (Z=-2.5D)




CHARGE AT BOTTOM (Z=-1.0D)



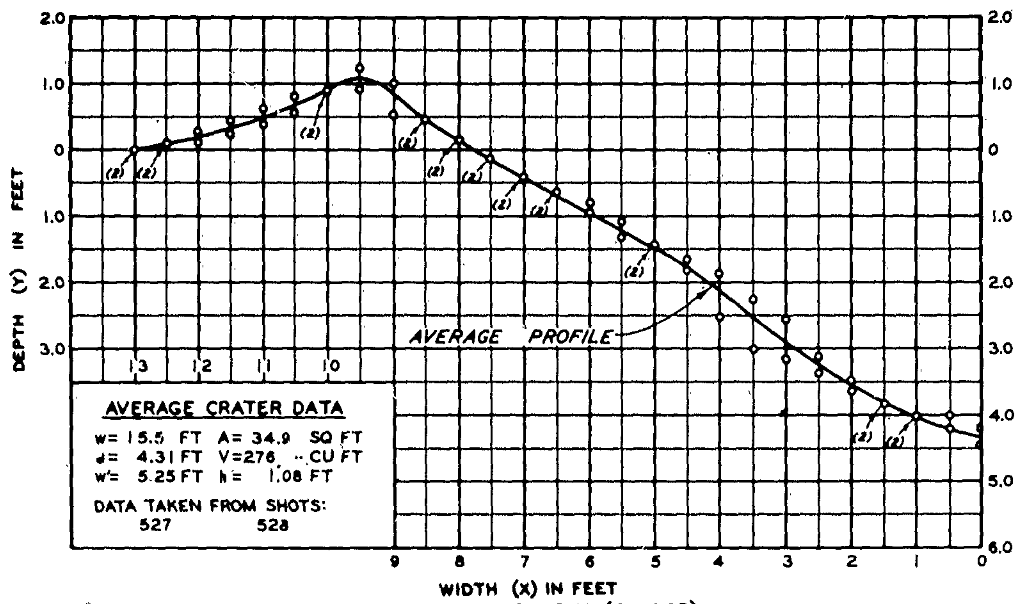
CRATER DIMENSIONS

## HALF-CRATER PROFILES

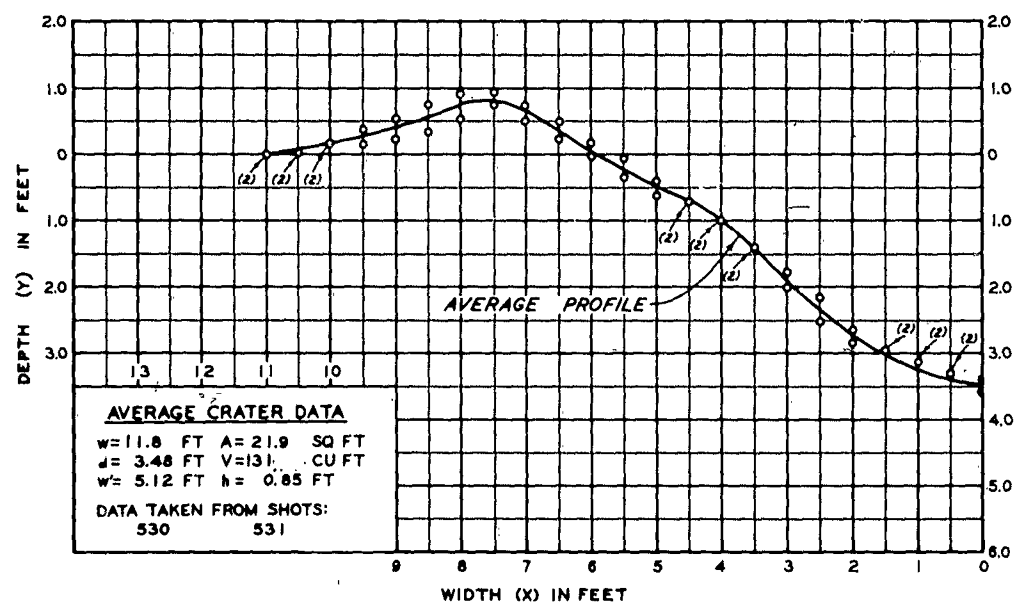
DIAMOND POINT CLAY

CHARGE WEIGHT – 4 LB

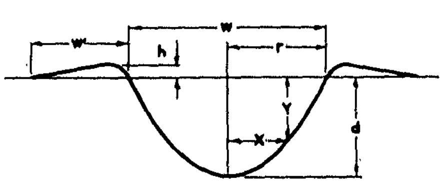
$D/W^{\frac{1}{3}} = 0.175$




CHARGE BELOW BOTTOM (Z=-2.5D)




CHARGE AT BOTTOM (Z=-1.0 D)




CRATER DIMENSIONS

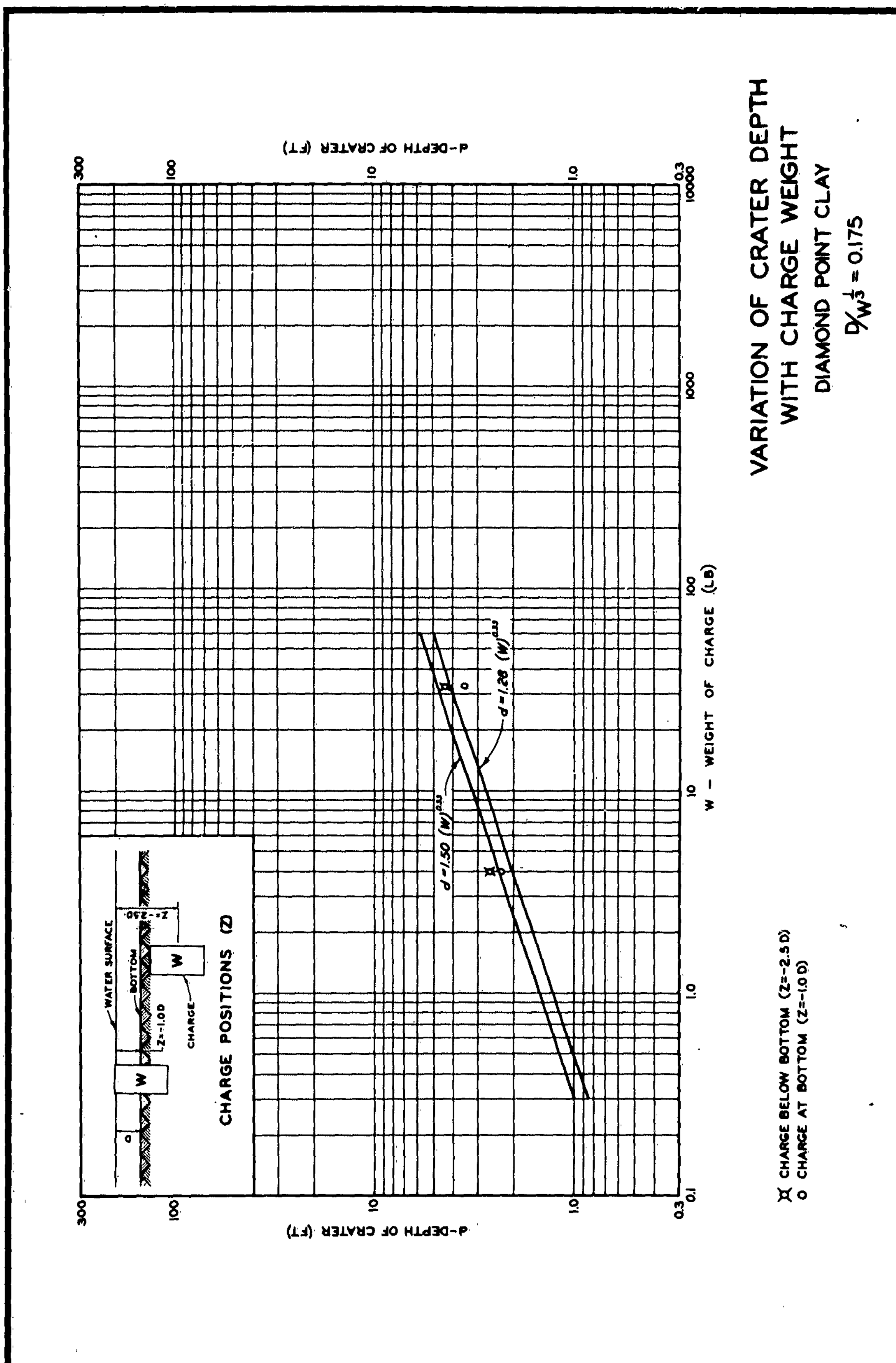
## HALF-CRATER PROFILES

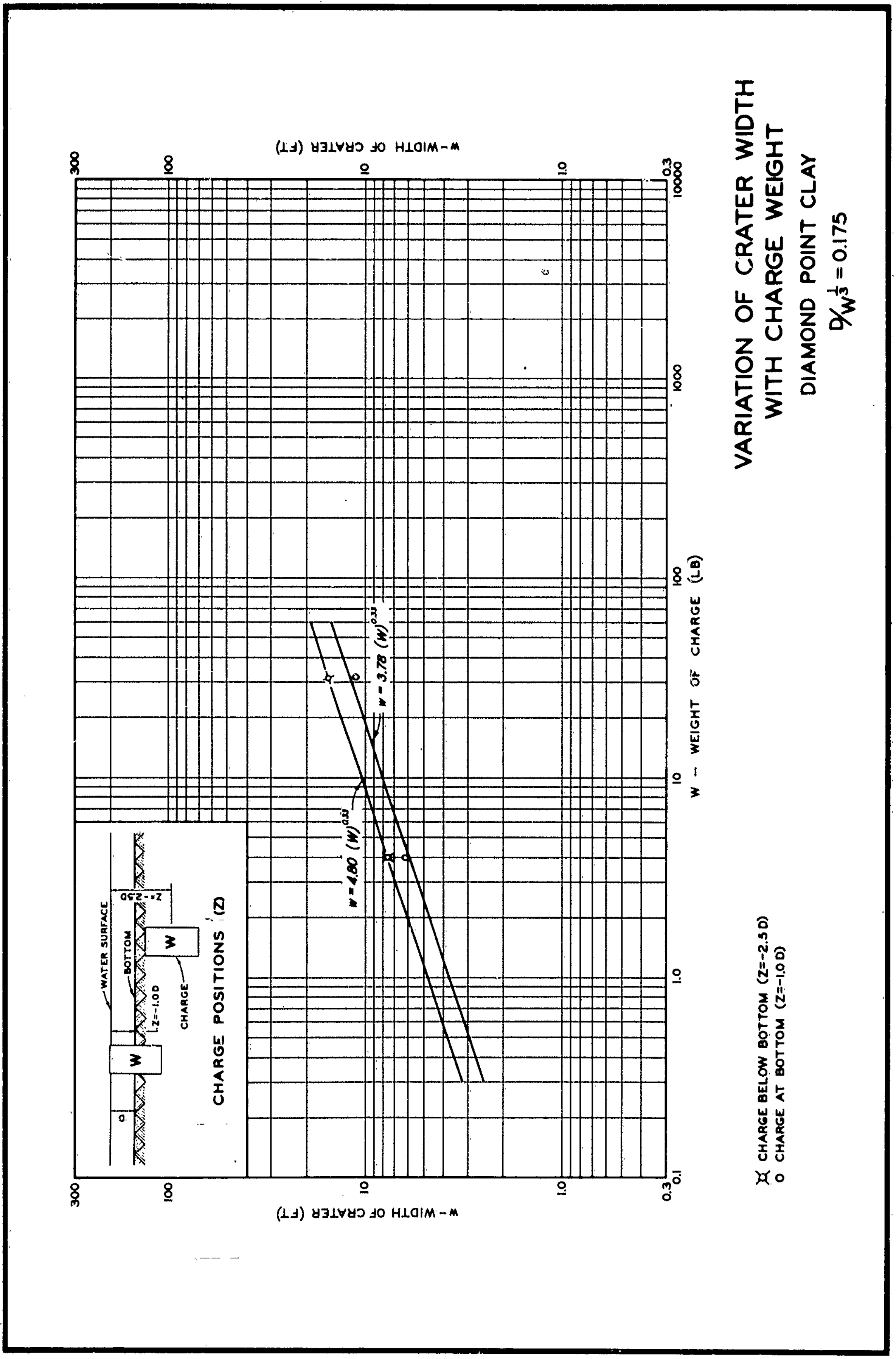
DIAMOND POINT CLAY

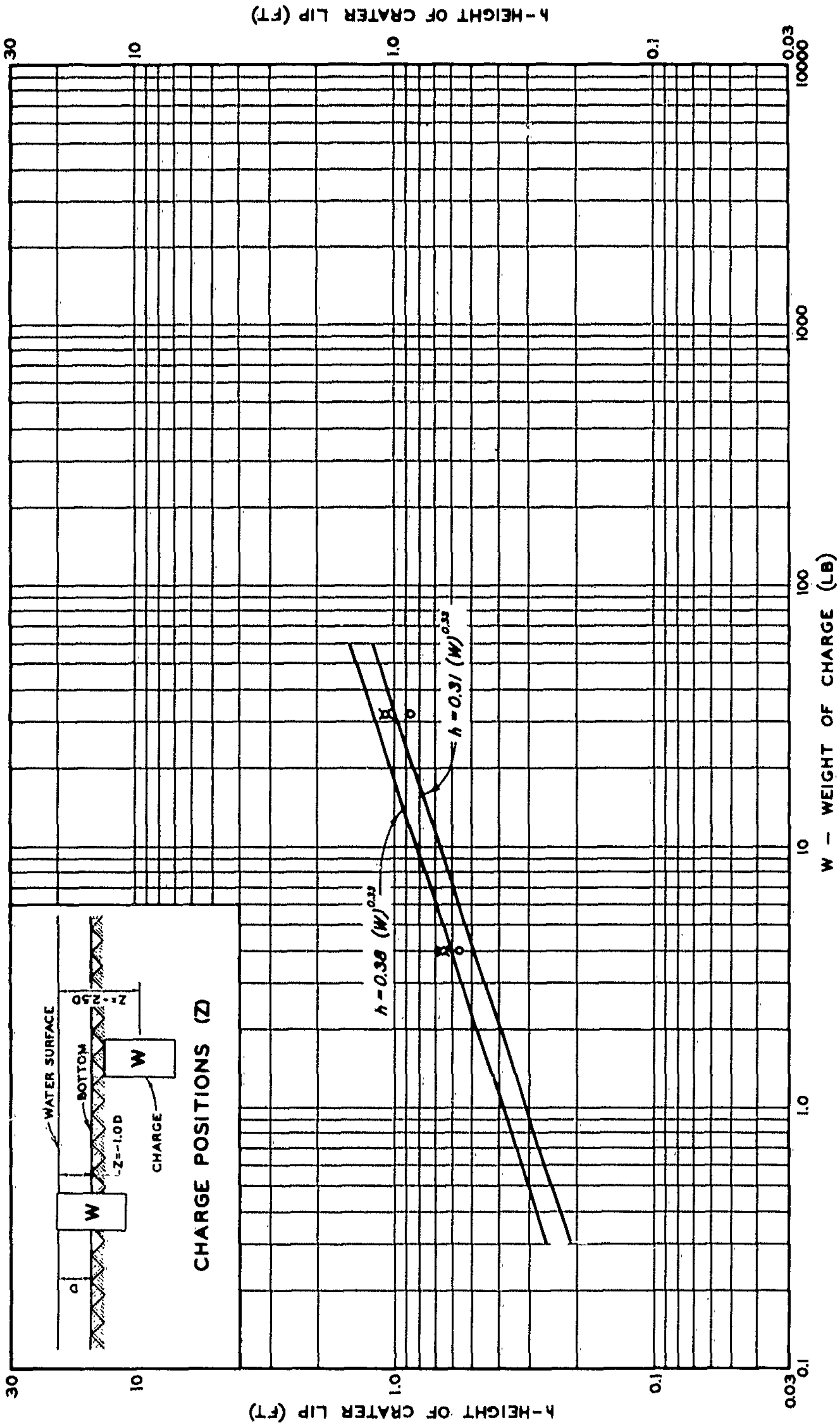
CHARGE WEIGHT - 32 LB

$D/W^{1/3} = 0.175$

PLATE 29


VARIATION OF CRATER DEPTH
WITH CHARGE WEIGHT
DIAMOND POINT CLAY
$D/W^{\frac{1}{3}} = 0.175$
d–DEPTH OF CRATER (FT)
W – WEIGHT OF CHARGE (LB)
$d = 1.28\ (W)^{0.33}$
$d = 1.50\ (W)^{0.33}$
WATER SURFACE
BOTTOM
CHARGE
Z=-1.0D
Z=-2.5D
W
CHARGE POSITIONS (Z)
⌧ CHARGE BELOW BOTTOM (Z=-2.5 D)
o CHARGE AT BOTTOM (Z=-1.0 D)


VARIATION OF CRATER WIDTH
WITH CHARGE WEIGHT
DIAMOND POINT CLAY
$D/W^{\frac{1}{3}} = 0.175$
w - WIDTH OF CRATER (FT)
W - WEIGHT OF CHARGE (LB)
$w = 4.80\,(W)^{0.33}$
$w = 3.78\,(W)^{0.33}$
CHARGE POSITIONS (Z)
WATER SURFACE
BOTTOM
CHARGE
Z=-1.0D
Z=-2.5D
W
CHARGE BELOW BOTTOM (Z=-2.5D)
O CHARGE AT BOTTOM (Z=-1.0D)
300
100
10
1.0
0.3
0.1
1.0
10
100
1000
10000



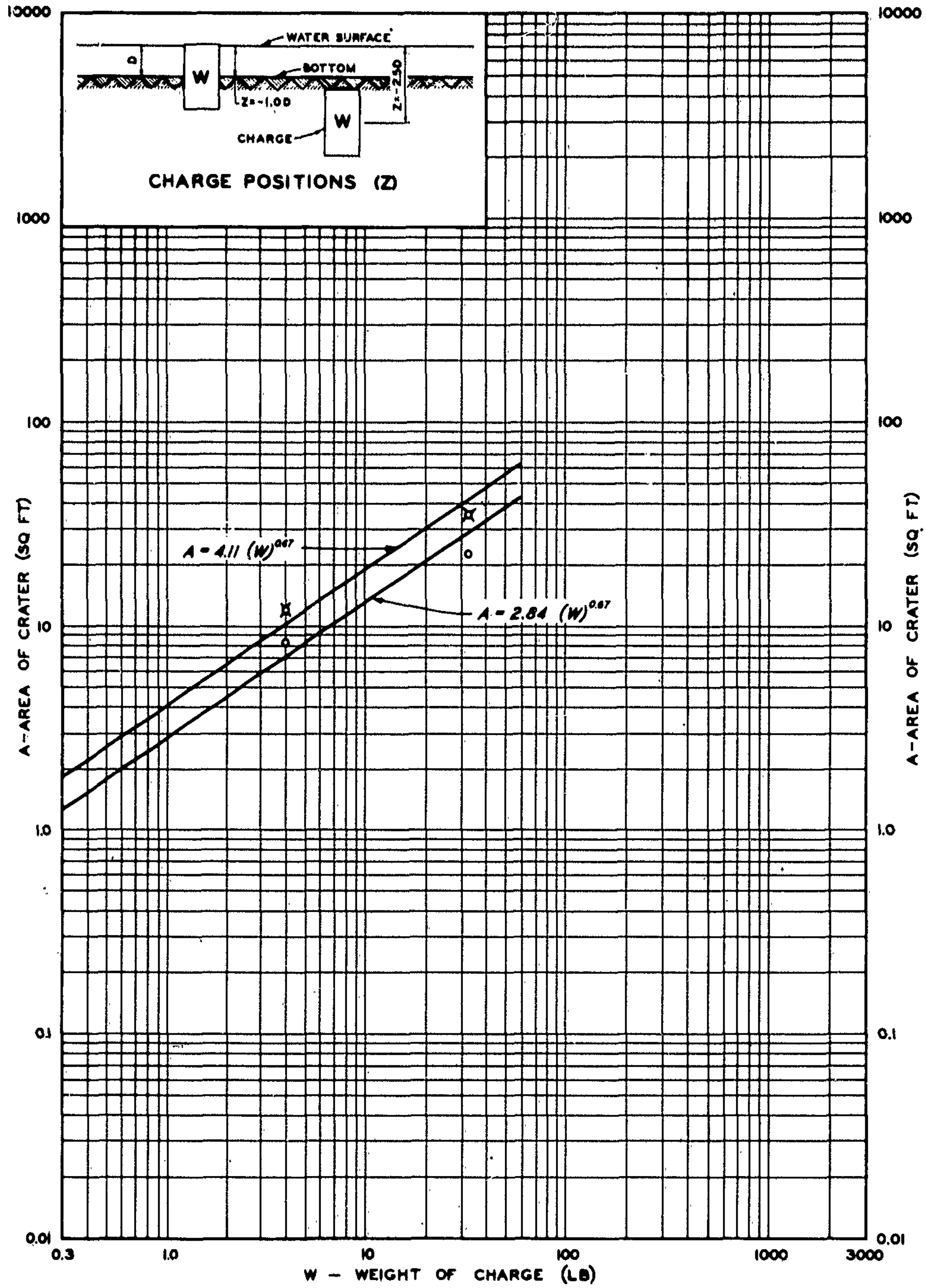

VARIATION OF CRATER LIP HEIGHT WITH CHARGE WEIGHT

DIAMOND POINT CLAY

$D/W^{\frac{1}{3}} = 0.175$

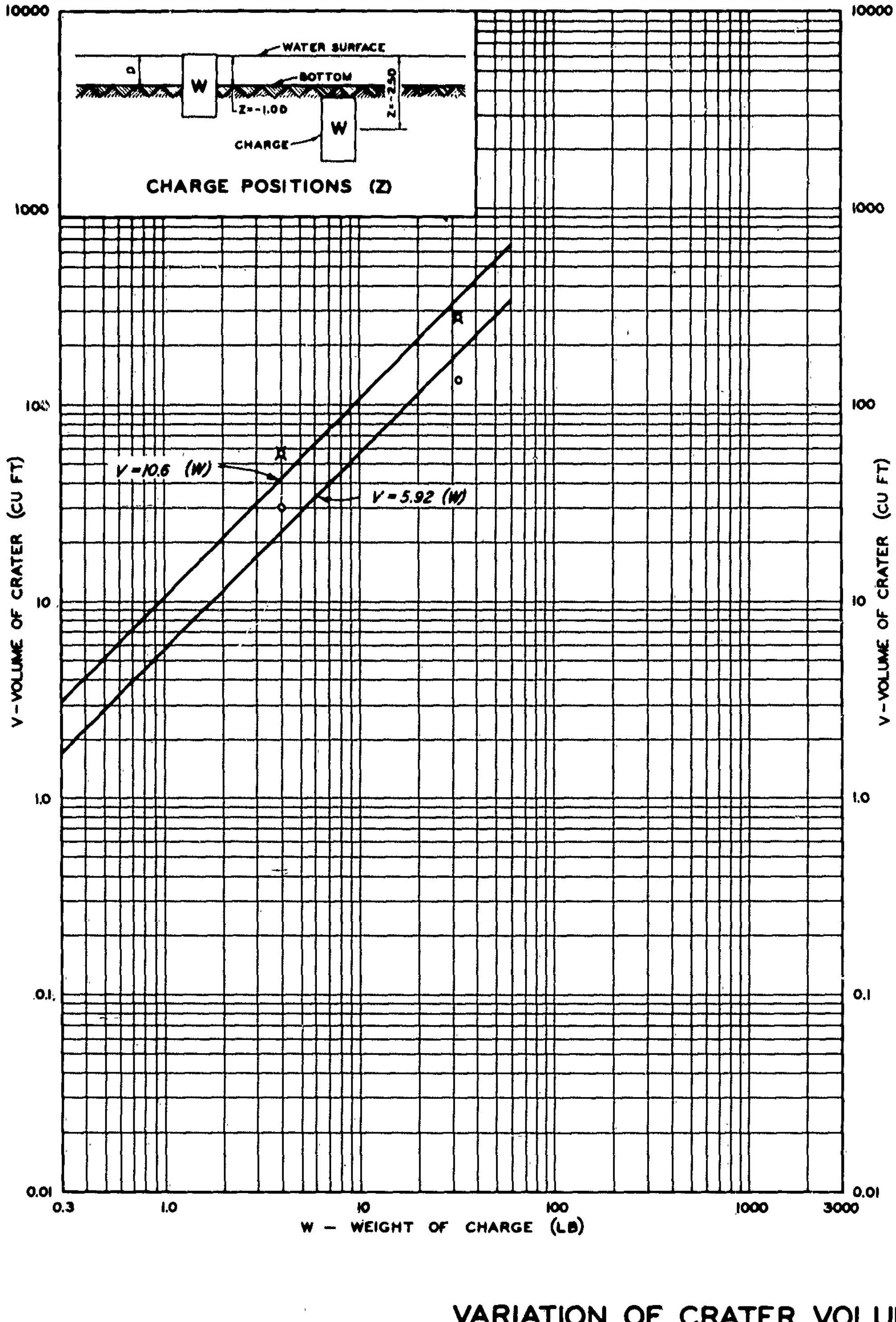
⌧ CHARGE BELOW BOTTOM (Z=-2.5 D)
o CHARGE AT BOTTOM (Z=-1.0 D)

PLATE 32




⌧ CHARGE BELOW BOTTOM (Z=-2.5 D)
o CHARGE AT BOTTOM (Z=-1.0 D)

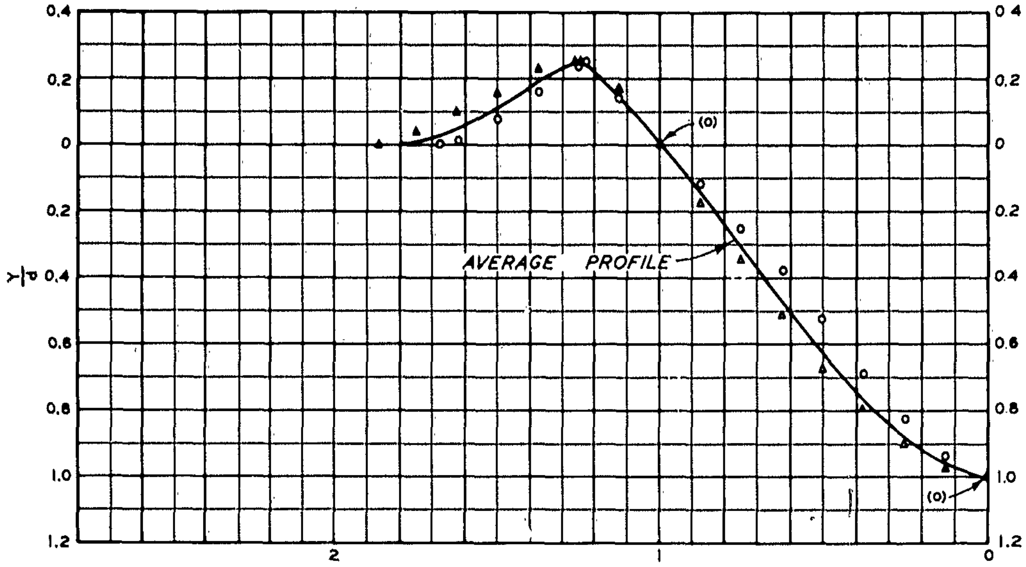
VARIATION OF CRATER AREA
WITH CHARGE WEIGHT
DIAMOND POINT CLAY
$D/W^{1/3} = 0.175$



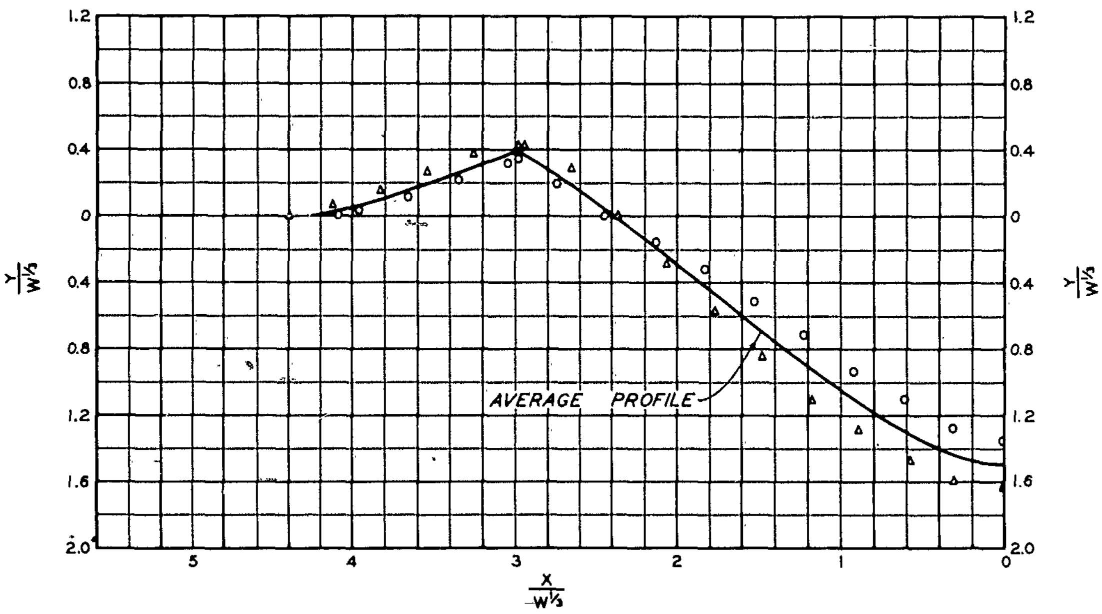

VARIATION OF CRATER VOLUME WITH CHARGE WEIGHT

DIAMOND POINT CLAY

$D/W^{\frac{1}{3}} = 0.175$




X/r vs Y/d




X/W⅓ vs Y/W⅓

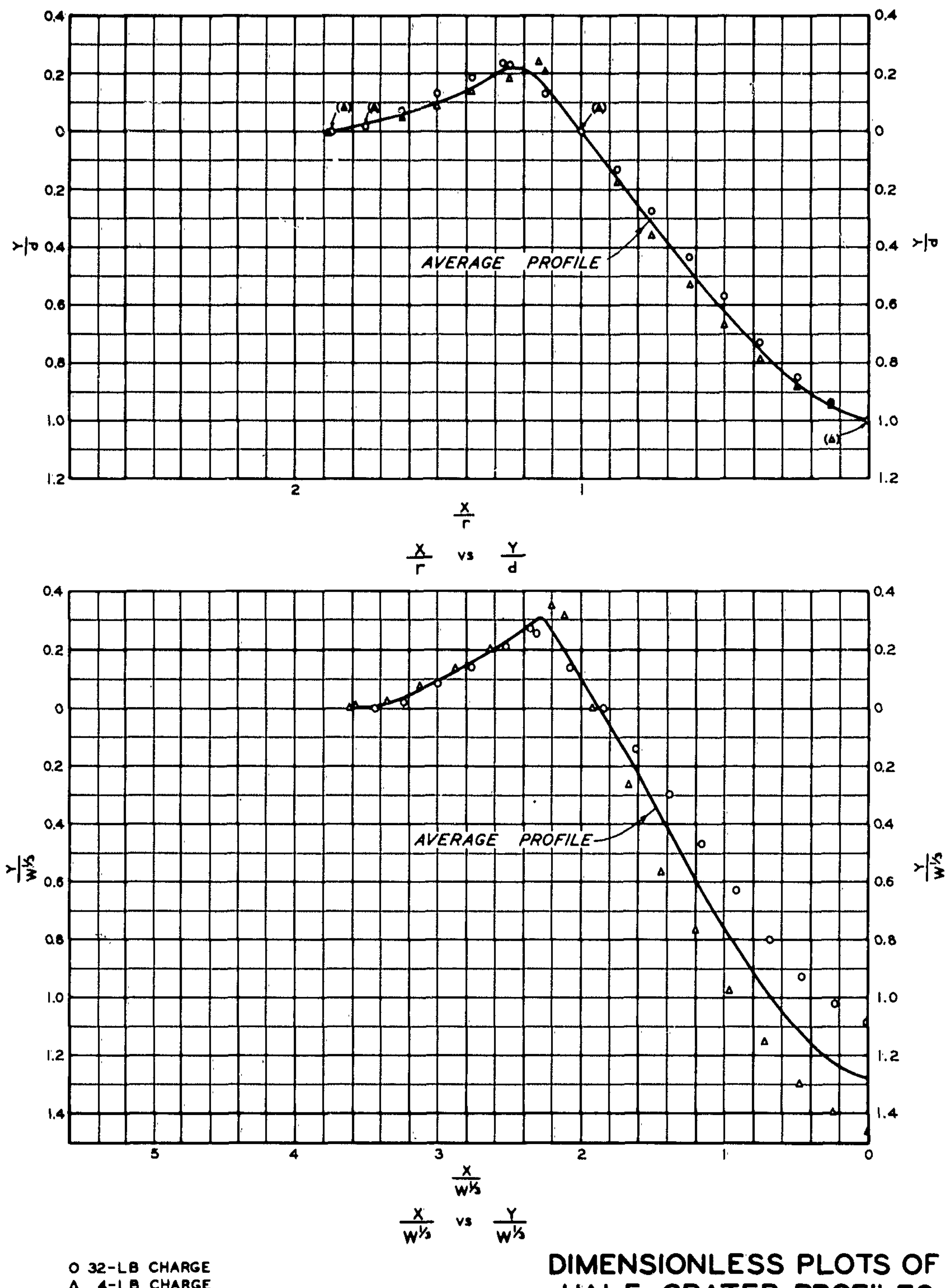
O 32-LB CHARGE
Δ 4-LB CHARGE

## DIMENSIONLESS PLOTS OF HALF-CRATER PROFILES

DIAMOND POINT CLAY

CHARGE BELOW BOTTOM (Z=−2.5 D)

$D/W^{\frac{1}{3}} = 0.175$




**DIMENSIONLESS PLOTS OF HALF-CRATER PROFILES**

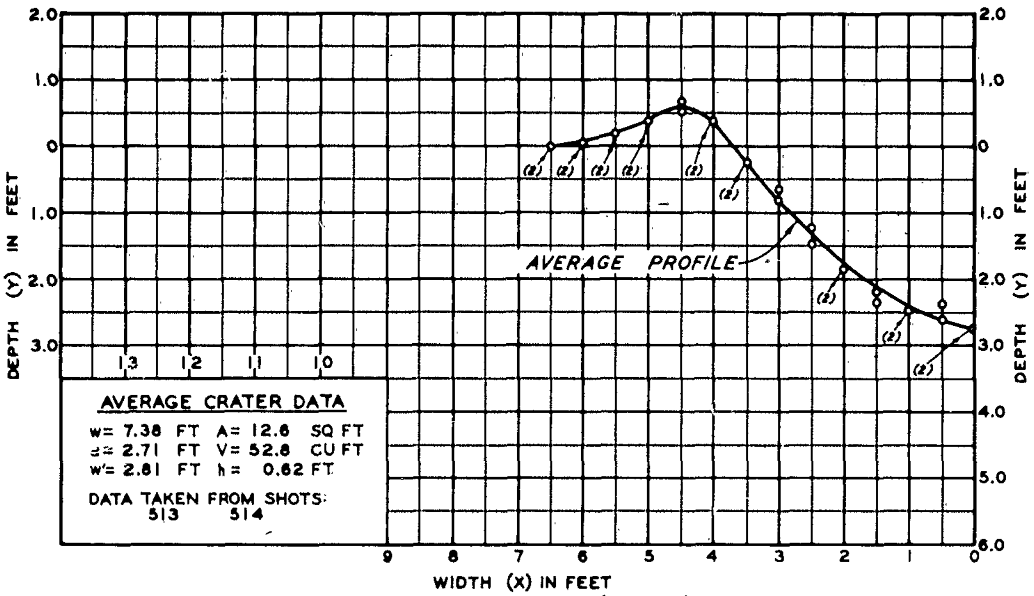
DIAMOND POINT CLAY

CHARGE AT BOTTOM (Z = −1.0 D)

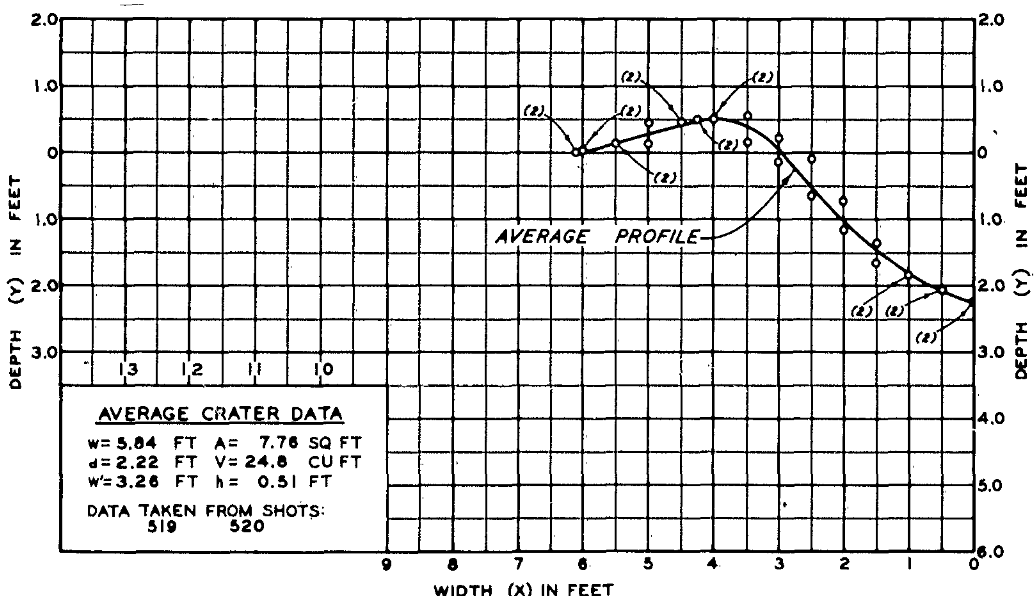
$D/W^{\frac{1}{3}} = 0.175$

# PLATES 37 - 45

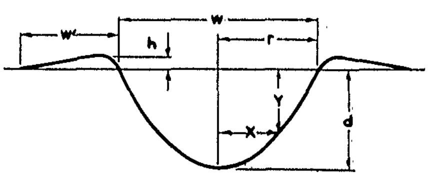
SCALED WATER DEPTH - 100 FT.




CHARGE BELOW BOTTOM (Z=-1.9D)



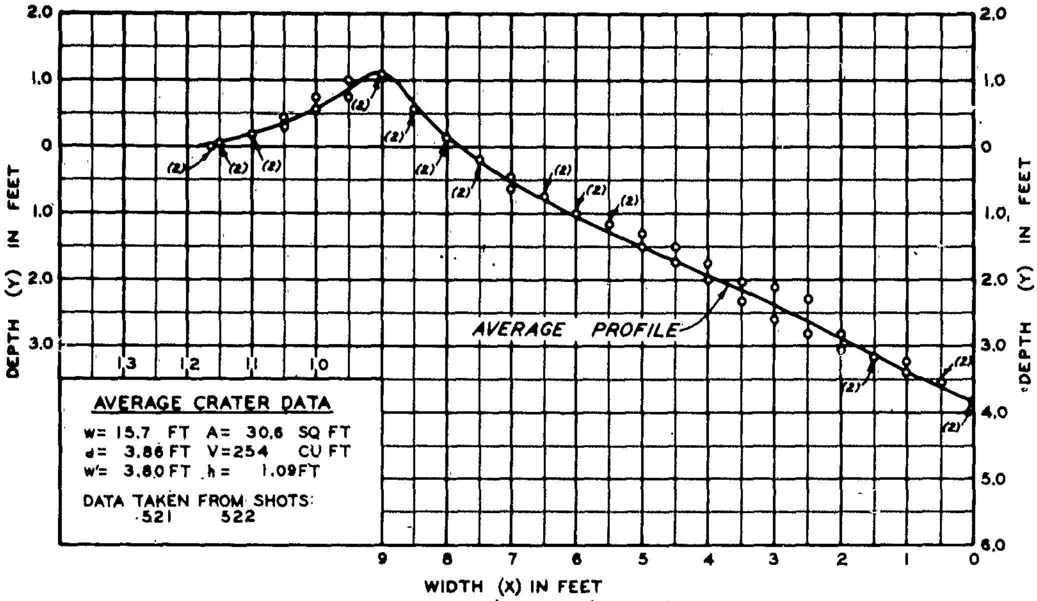

CHARGE AT BOTTOM (Z=-1.0D)



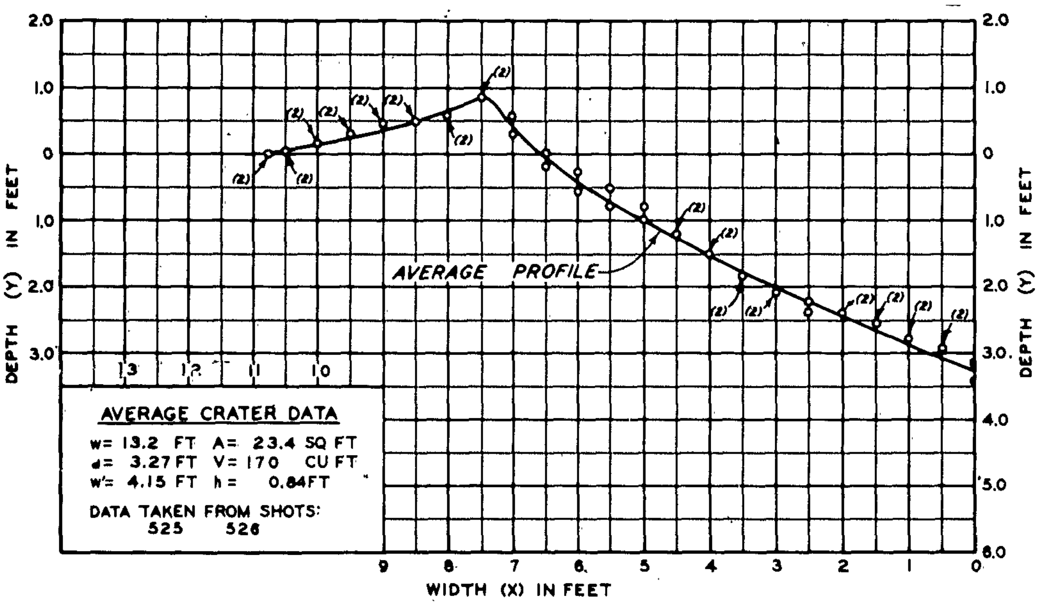

CRATER DIMENSIONS

## HALF-CRATER PROFILES
DIAMOND POINT CLAY
CHARGE WEIGHT – 4 LB
$D/W^{\frac{1}{3}} = 0.292$

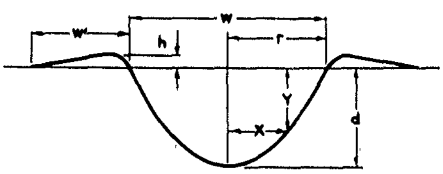
PLATE 37




CHARGE BELOW BOTTOM (Z=-1.9D)



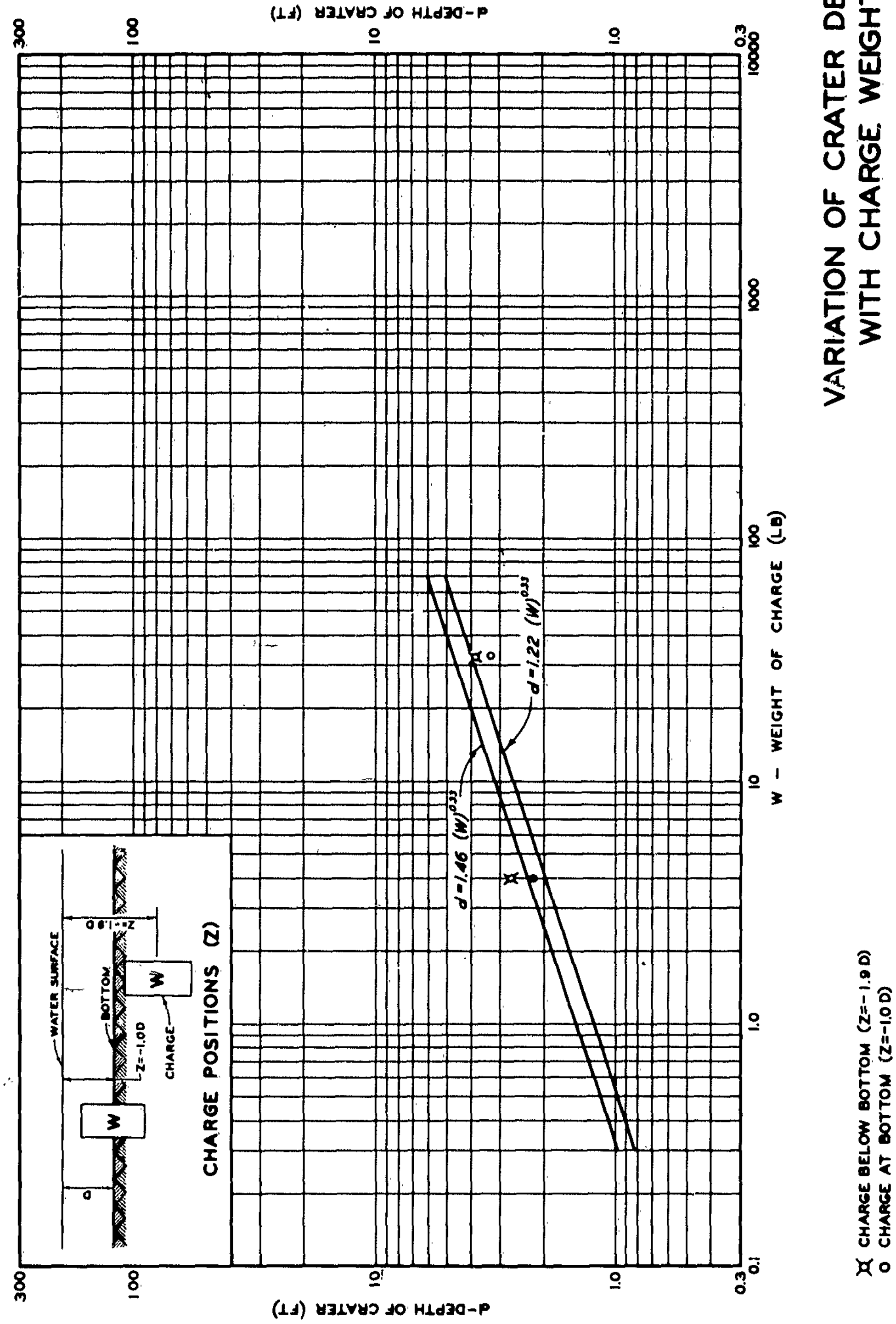

CHARGE AT BOTTOM (Z=-1.0 D)




CRATER DIMENSIONS

## HALF-CRATER PROFILES
DIAMOND POINT CLAY
CHARGE WEIGHT - 32 LB
$D/W^{1/3} = 0.292$

PLATE 38




VARIATION OF CRATER DEPTH WITH CHARGE WEIGHT
DIAMOND POINT CLAY
$D/W^{\frac{1}{3}} = 0.292$

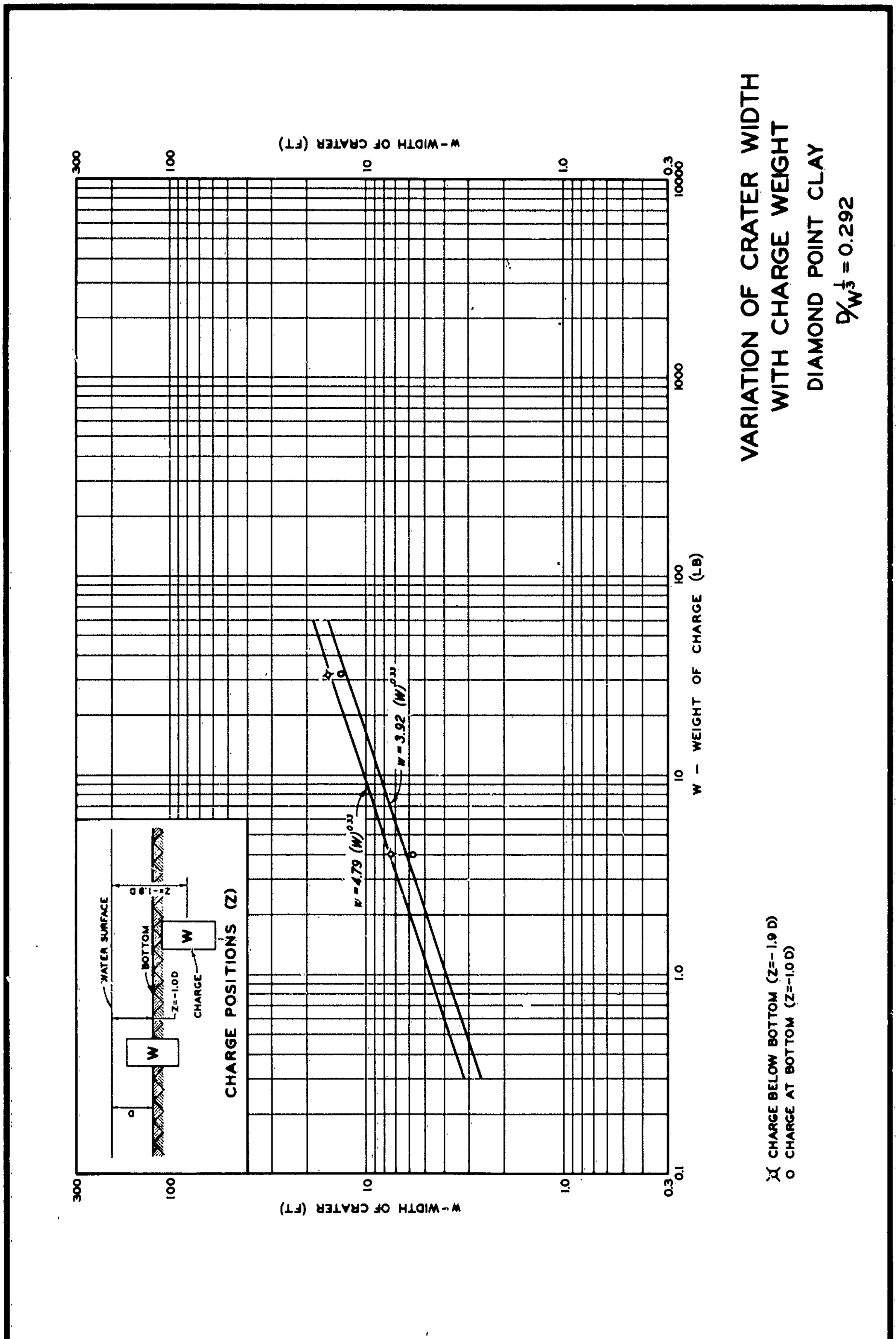
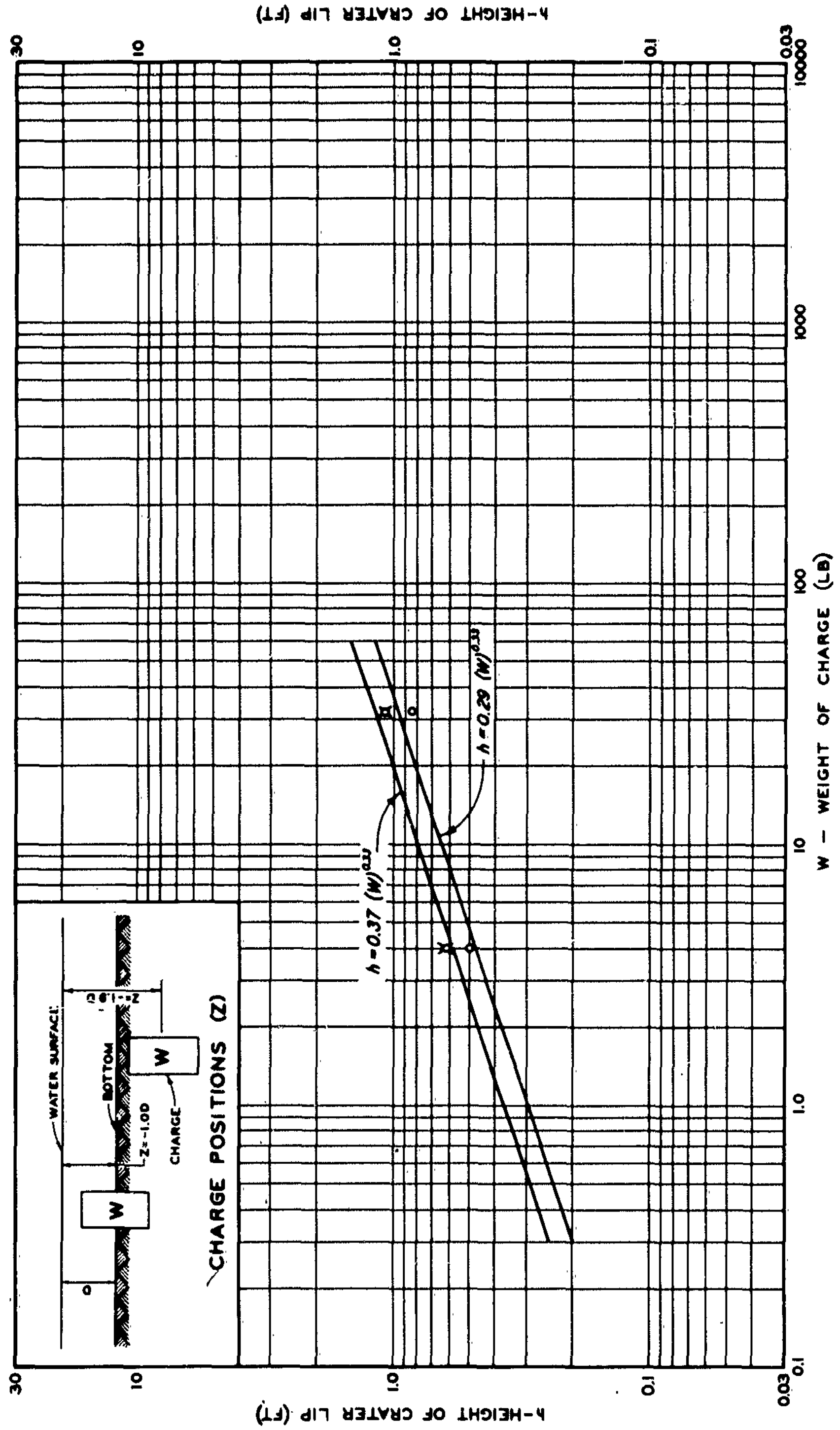

VARIATION OF CRATER WIDTH
WITH CHARGE WEIGHT
DIAMOND POINT CLAY
$D/W^{\frac{1}{3}} = 0.292$
W - WIDTH OF CRATER (FT)
W - WEIGHT OF CHARGE (LB)
$w = 3.92\ (W)^{0.33}$
$w = 4.79\ (W)^{0.33}$
CHARGE POSITIONS (Z)
WATER SURFACE
BOTTOM
CHARGE
Z=-1.0D
Z=-1.9D
D
W
W
⌧ CHARGE BELOW BOTTOM (Z=-1.9 D)
o CHARGE AT BOTTOM (Z=-1.0 D)

PLATE 40

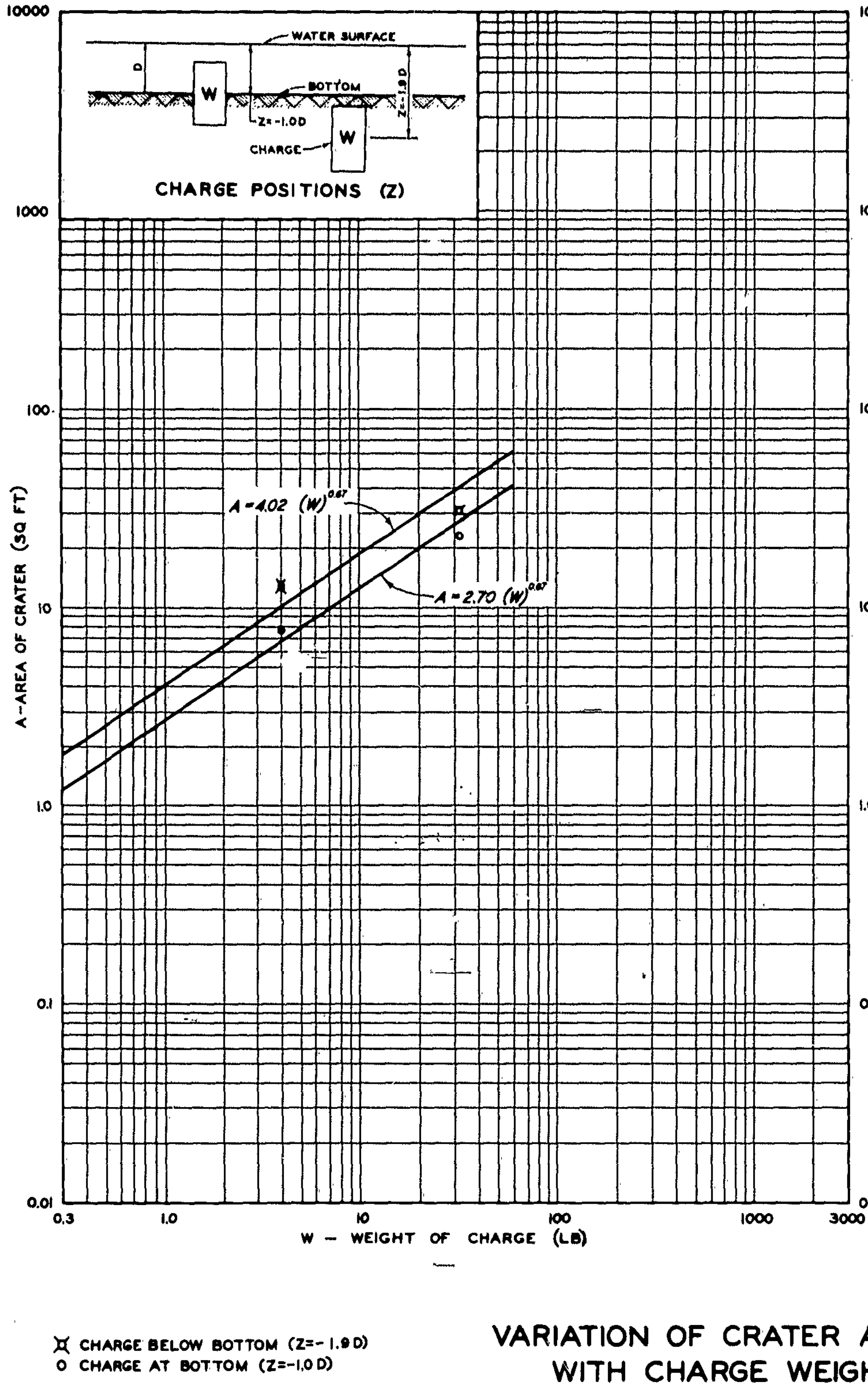



# VARIATION OF CRATER LIP HEIGHT WITH CHARGE WEIGHT

DIAMOND POINT CLAY

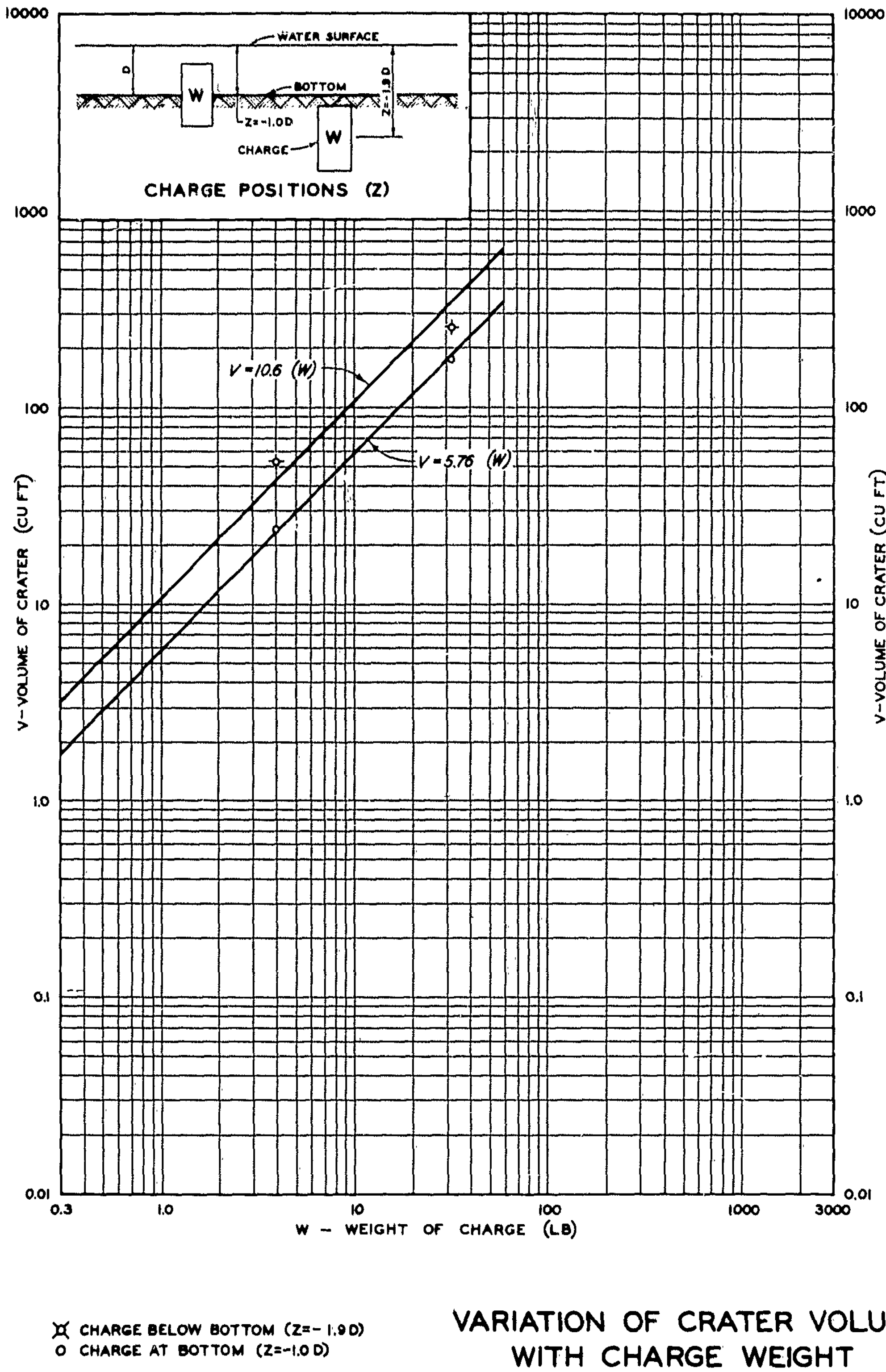
$D/W^{1/3} = 0.292$

⌘ CHARGE BELOW BOTTOM (Z=-1.9D)
o CHARGE AT BOTTOM (Z=-1.0D)

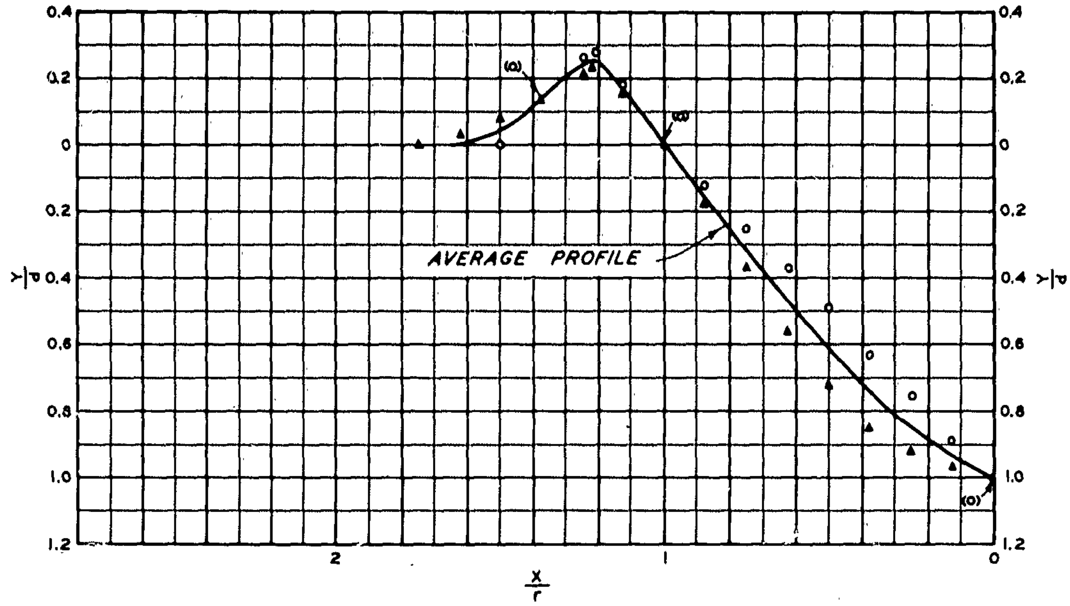



VARIATION OF CRATER AREA
WITH CHARGE WEIGHT
DIAMOND POINT CLAY

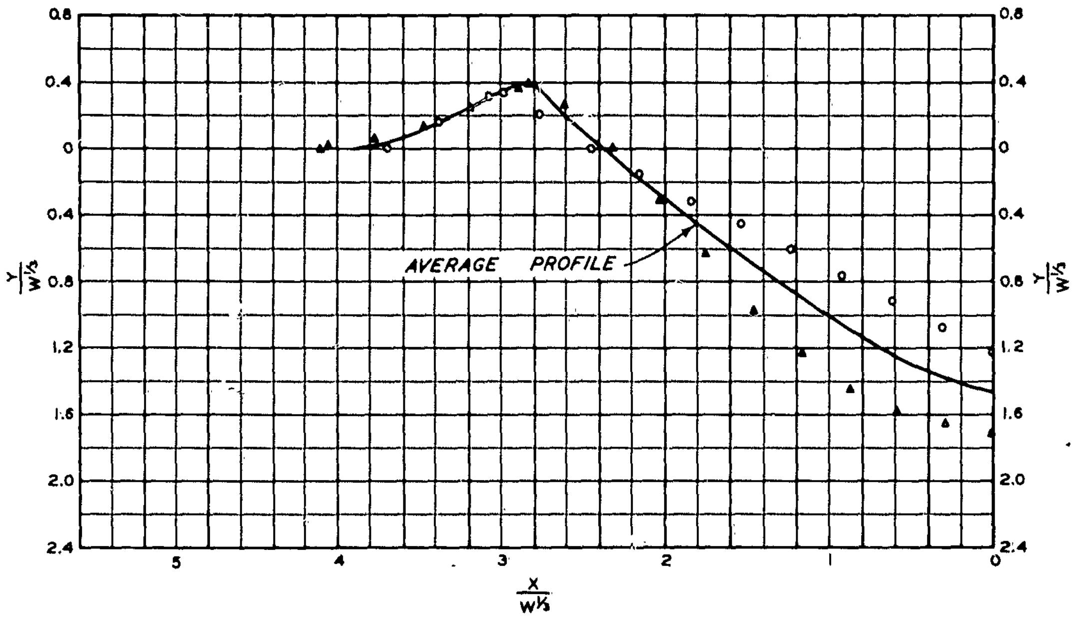
$D/W^{\frac{1}{3}} = 0.292$




VARIATION OF CRATER VOLUME
WITH CHARGE WEIGHT
DIAMOND POINT CLAY
$D/W^{\frac{1}{3}} = 0.292$




X/r vs Y/d

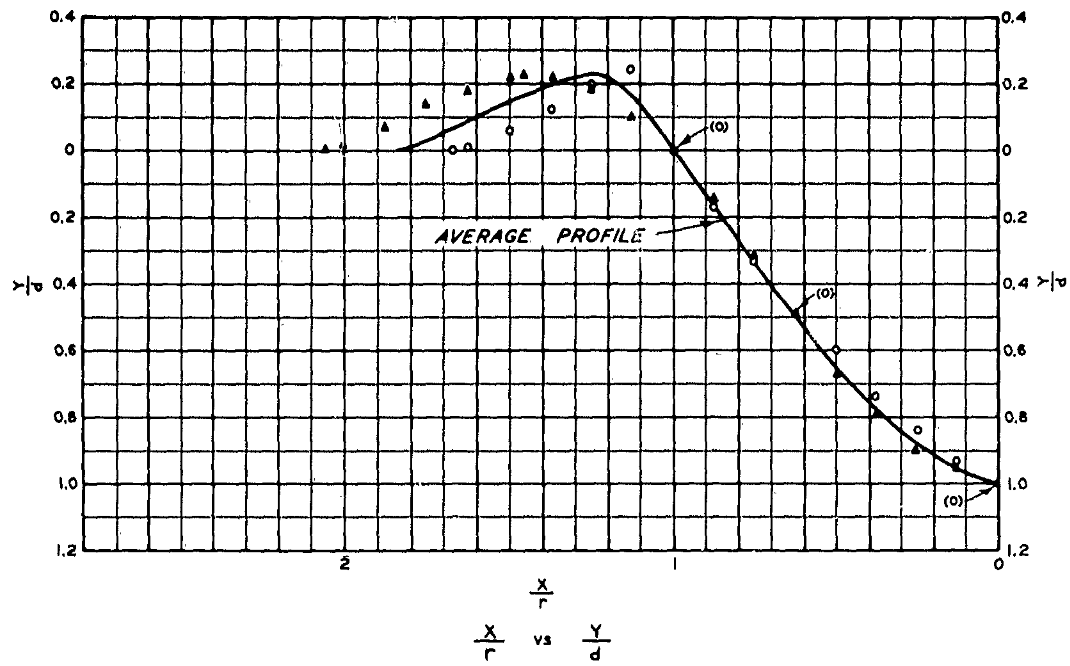


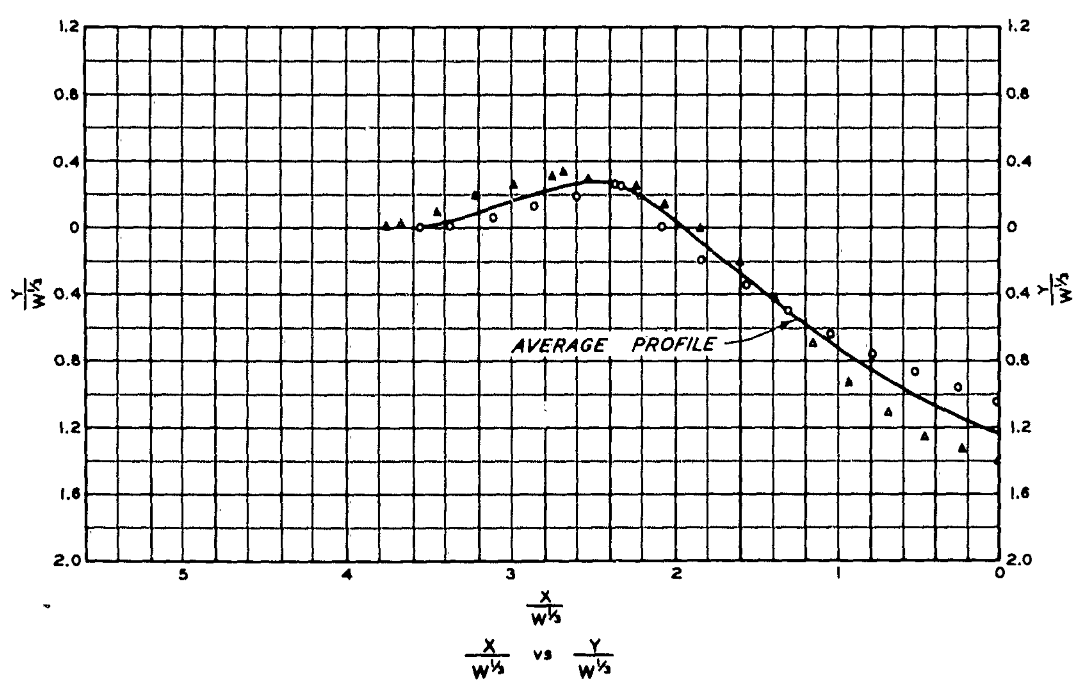

X/W^1/3 vs Y/W^1/3

O 32-LB CHARGE
Δ 4-LB CHARGE

DIMENSIONLESS PLOTS OF
HALF-CRATER PROFILES
DIAMOND POINT CLAY
CHARGE BELOW BOTTOM (Z=-1.9D)
$D/W^{\frac{1}{3}} = 0.292$

PLATE 44




O 32-LB CHARGE
Δ 4-LB CHARGE

**DIMENSIONLESS PLOTS OF HALF-CRATER PROFILES**

DIAMOND POINT CLAY

CHARGE AT BOTTOM (Z=-1.0 D)

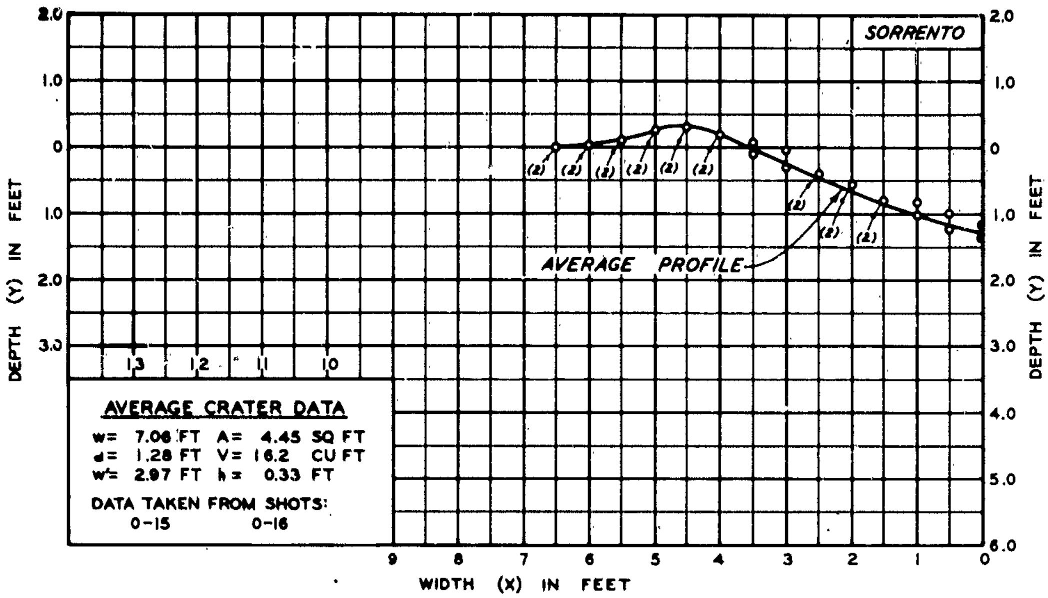
$D/W^{\frac{1}{3}} = 0.292$

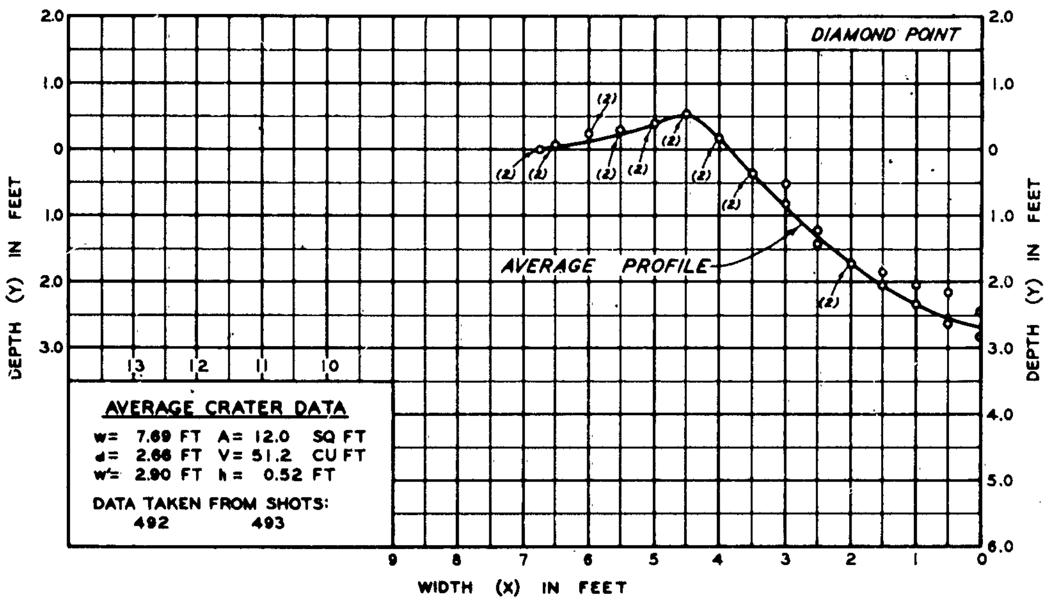


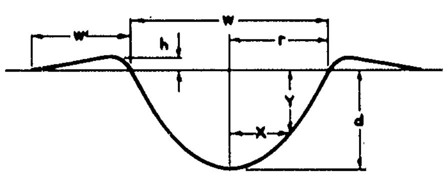
CONFIDENTIAL
Security Information

# PLATES 46 - 72

SCALED WATER DEPTH - 200 FT.




CRATER DIMENSIONS

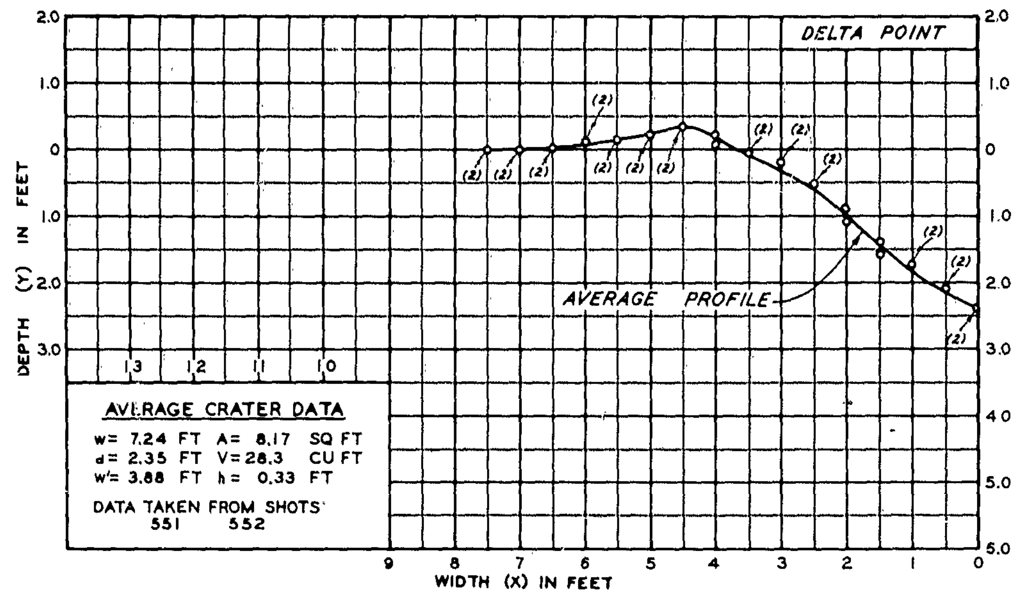
## HALF-CRATER PROFILES

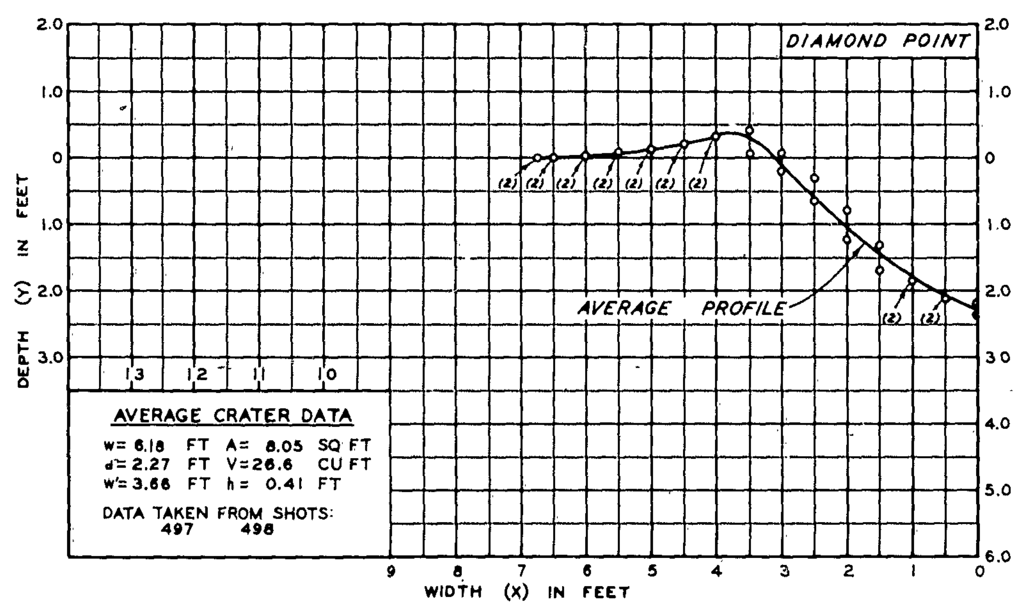
BOTTOM MATERIAL - CLAY

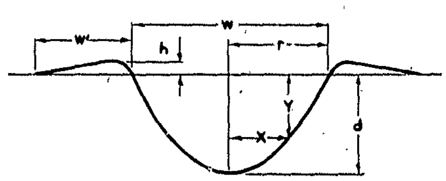
CHARGE BELOW BOTTOM (Z=-1.45D)

CHARGE WEIGHT - 4 LB

$D/W^{\frac{1}{3}} = 0.585$



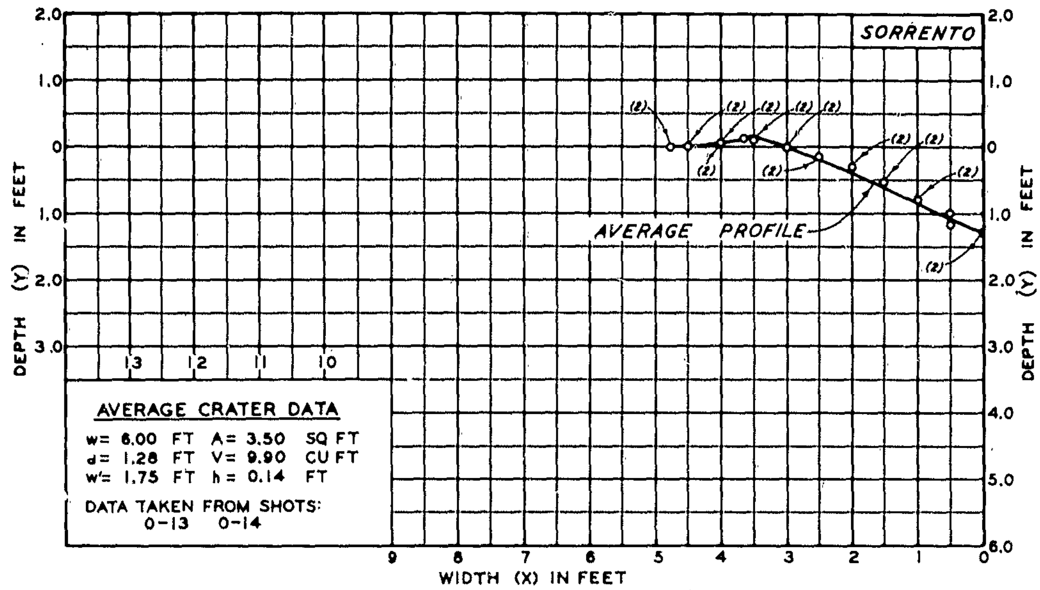



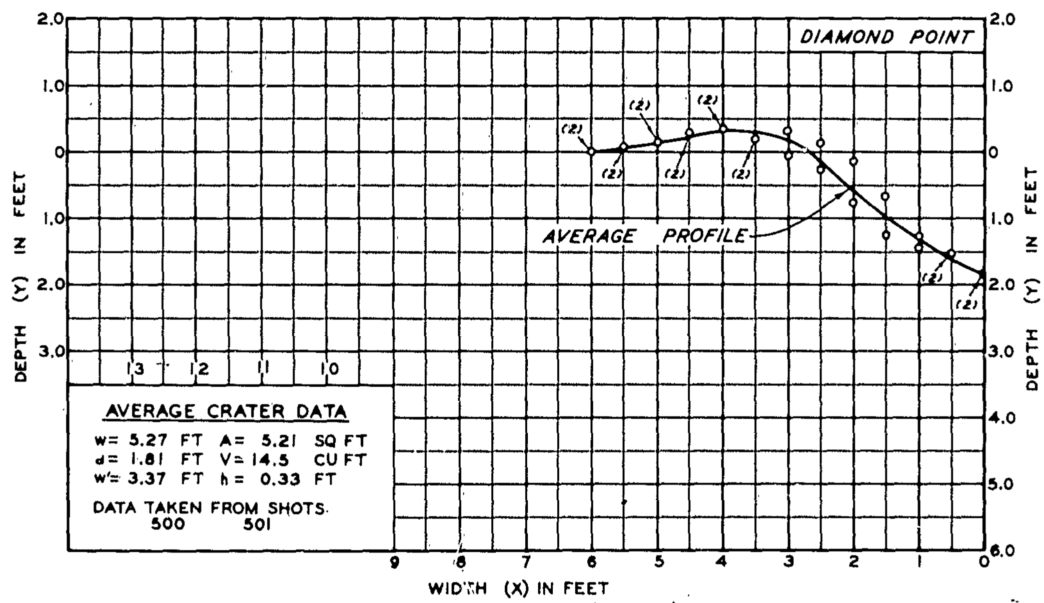

CRATER DIMENSIONS

## HALF-CRATER PROFILES

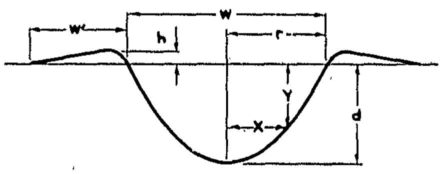
BOTTOM MATERIAL - CLAY
CHARGE AT BOTTOM (Z=-1.0D)
CHARGE WEIGHT - 4 LB
$D/W^{\frac{1}{3}} = 0.585$




CHARGE AT BOTTOM (Z=-1.0 D)



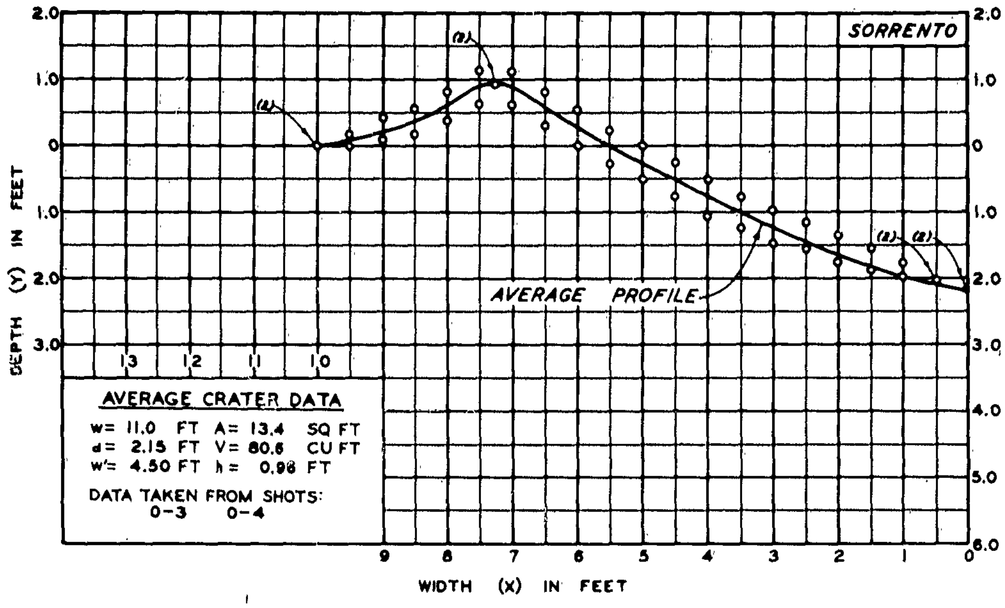

CHARGE AT MID-DEPTH (Z=-0.5D)

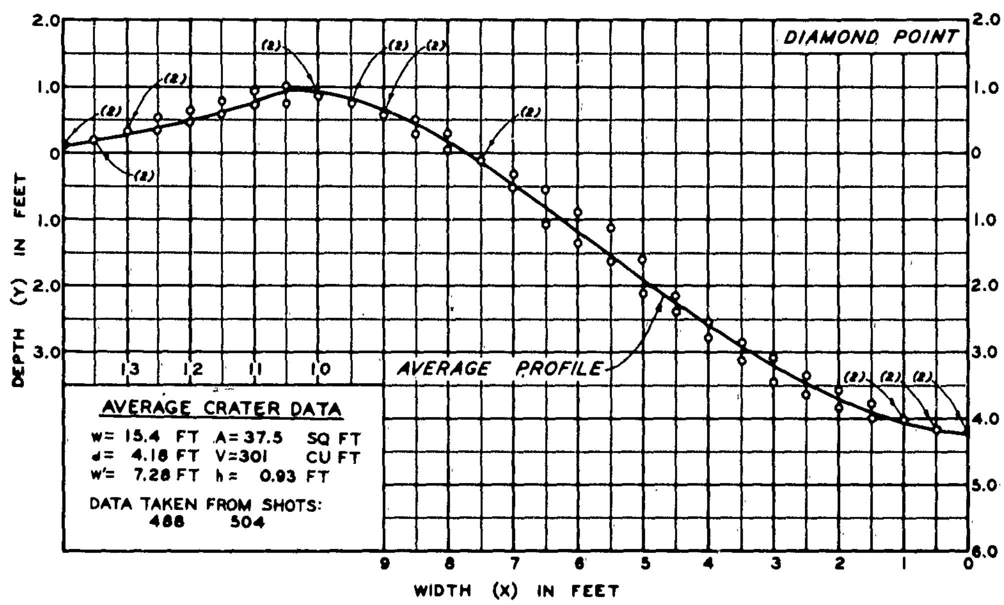


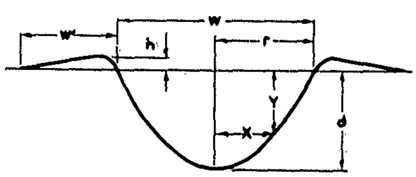

CRATER DIMENSIONS

## HALF-CRATER PROFILES

BOTTOM MATERIAL - CLAY
CHARGE POSITIONS AS SHOWN
CHARGE WEIGHT - 4 LB
$D/W^{\frac{1}{3}} = 0.585$



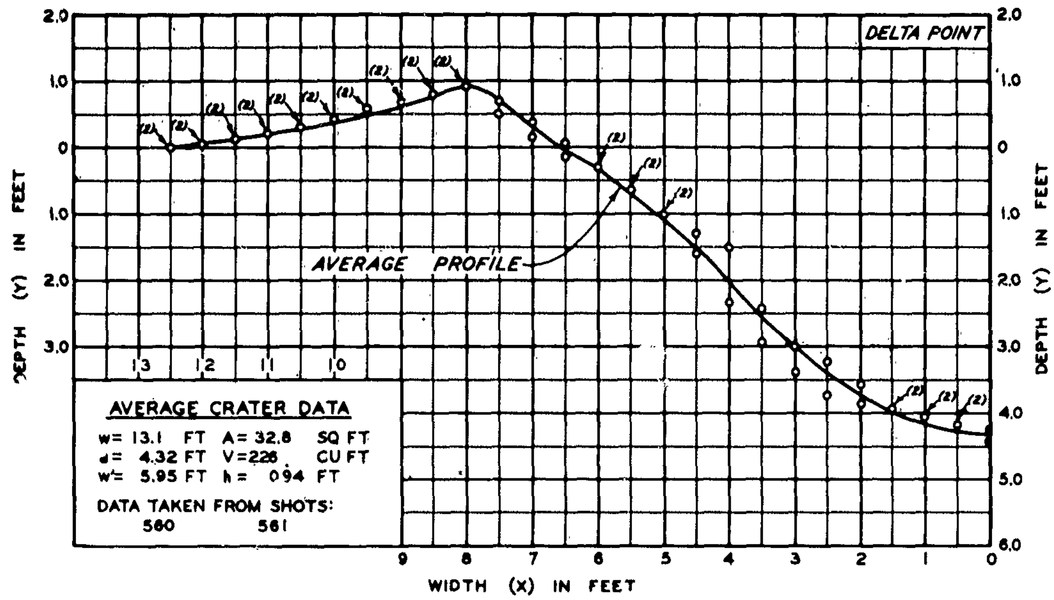



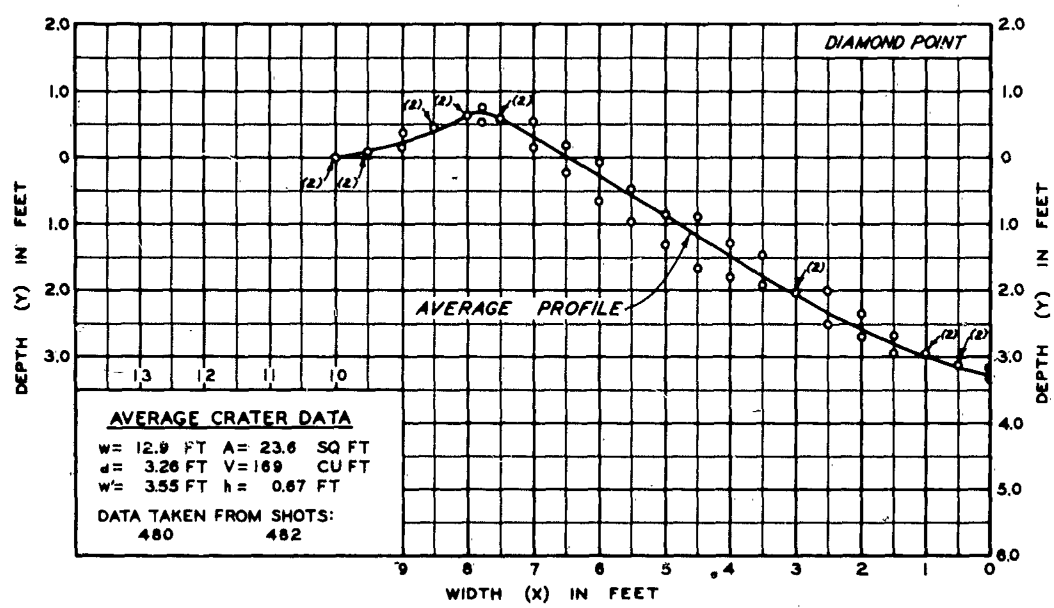

CRATER DIMENSIONS

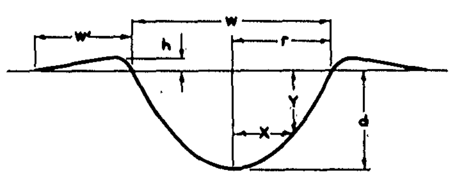
## HALF-CRATER PROFILES

BOTTOM MATERIAL - CLAY
CHARGE BELOW BOTTOM (Z=-1.45D)
CHARGE WEIGHT - 32LB

$D/W^{1/3} = 0.585$



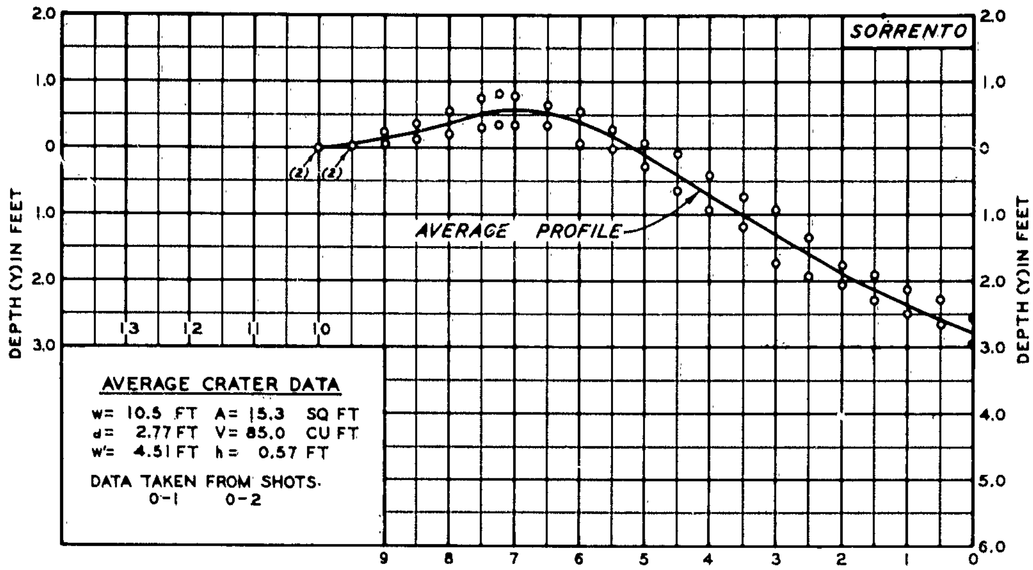



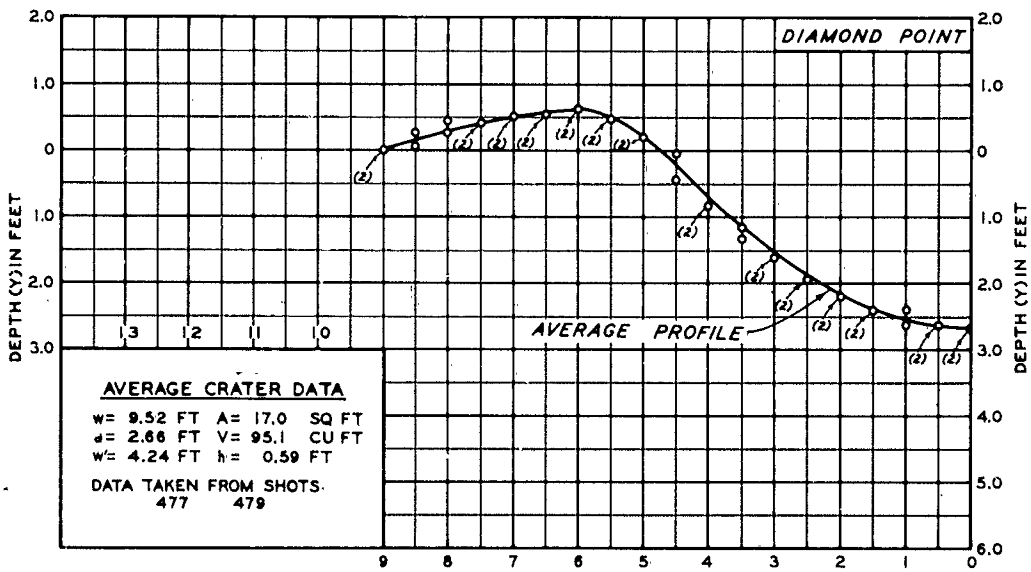

CRATER DIMENSIONS

## HALF-CRATER PROFILES

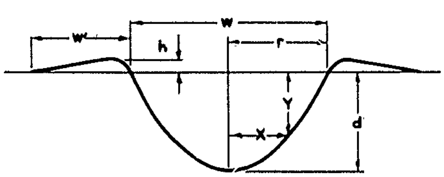
BOTTOM MATERIAL - CLAY
CHARGE AT BOTTOM (Z = -1.0 D)
CHARGE WEIGHT - 32 LB
$D/W^{\frac{1}{3}} = 0.585$




WIDTH (X) IN FEET
CHARGE AT BOTTOM (Z=-1.0 D)




WIDTH (X) IN FEET
CHARGE AT MID-DEPTH (Z=-0.5D)




CRATER DIMENSIONS

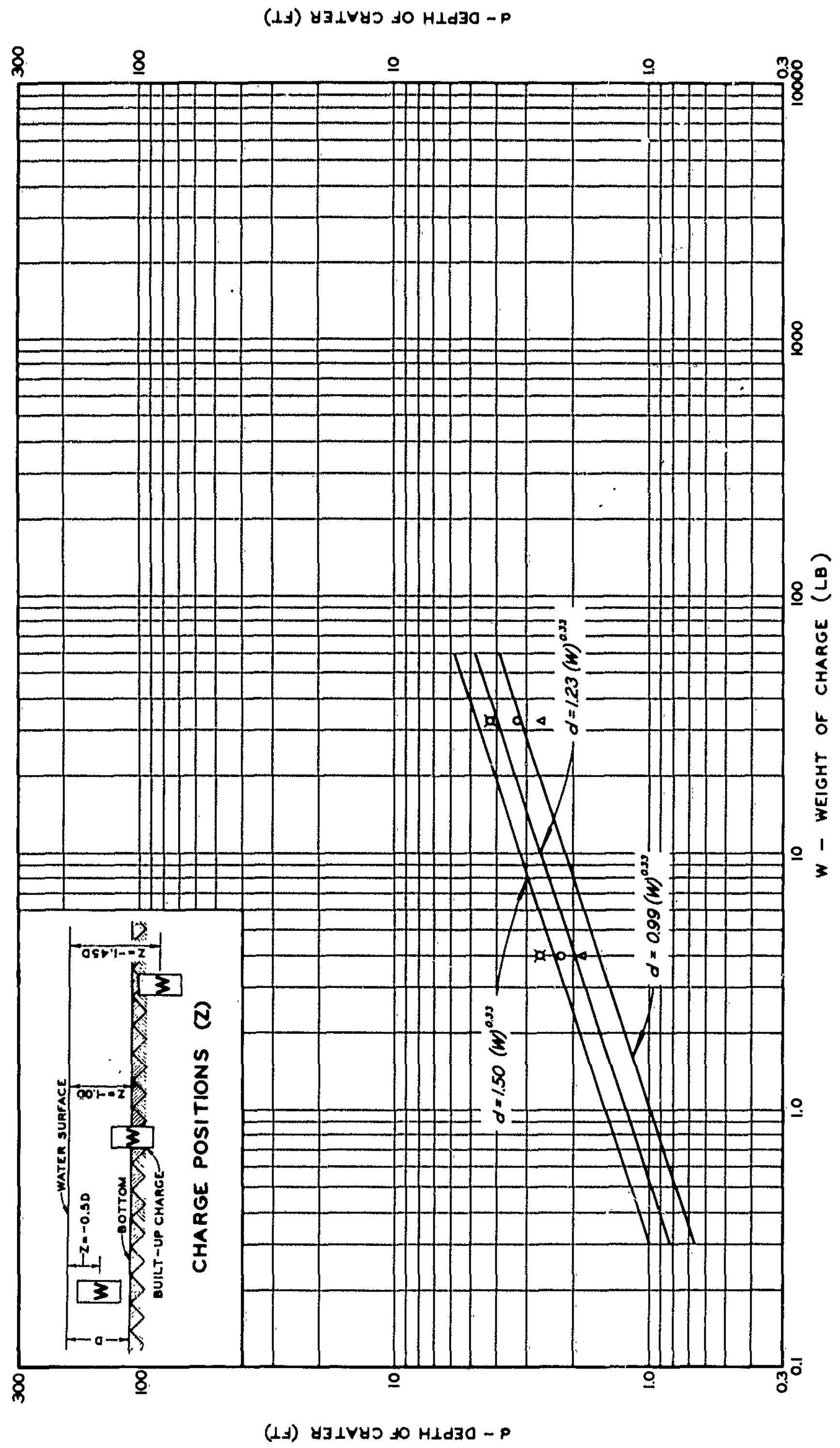
## HALF-CRATER PROFILES

BOTTOM MATERIAL-CLAY
CHARGE POSITION AS SHOWN
CHARGE WEIGHT-32 LB
$D/W^{\frac{1}{3}} = 0.585$

# VARIATION OF CRATER DEPTH WITH CHARGE WEIGHT

DIAMOND POINT CLAY

$D/W^{\frac{1}{3}} = 0.585$




⌑ CHARGE BELOW BOTTOM (Z = -1.45 D)
○ CHARGE AT BOTTOM (Z = -1.0 D)
△ CHARGE AT MID-DEPTH (Z = -0.5 D)

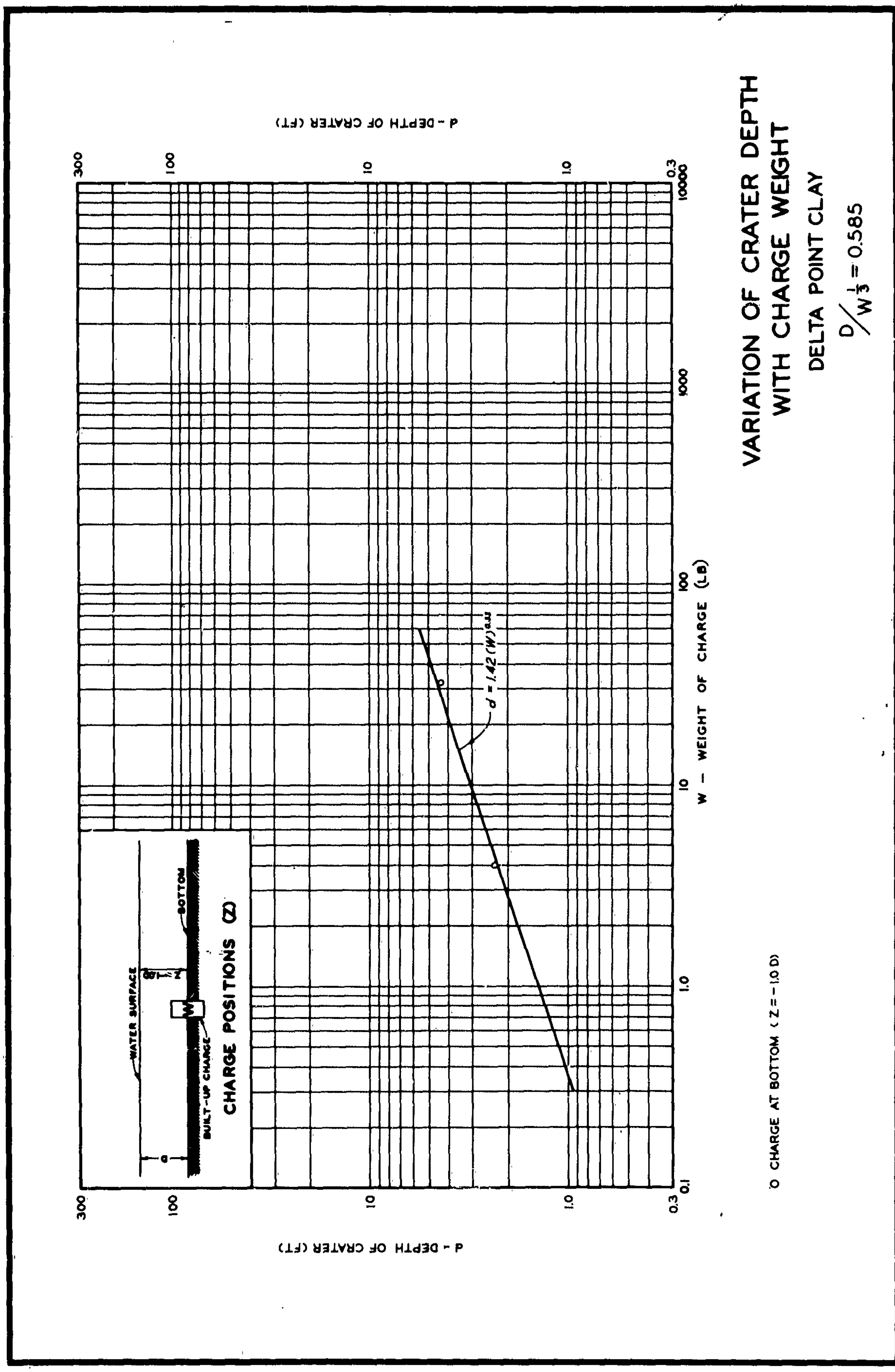
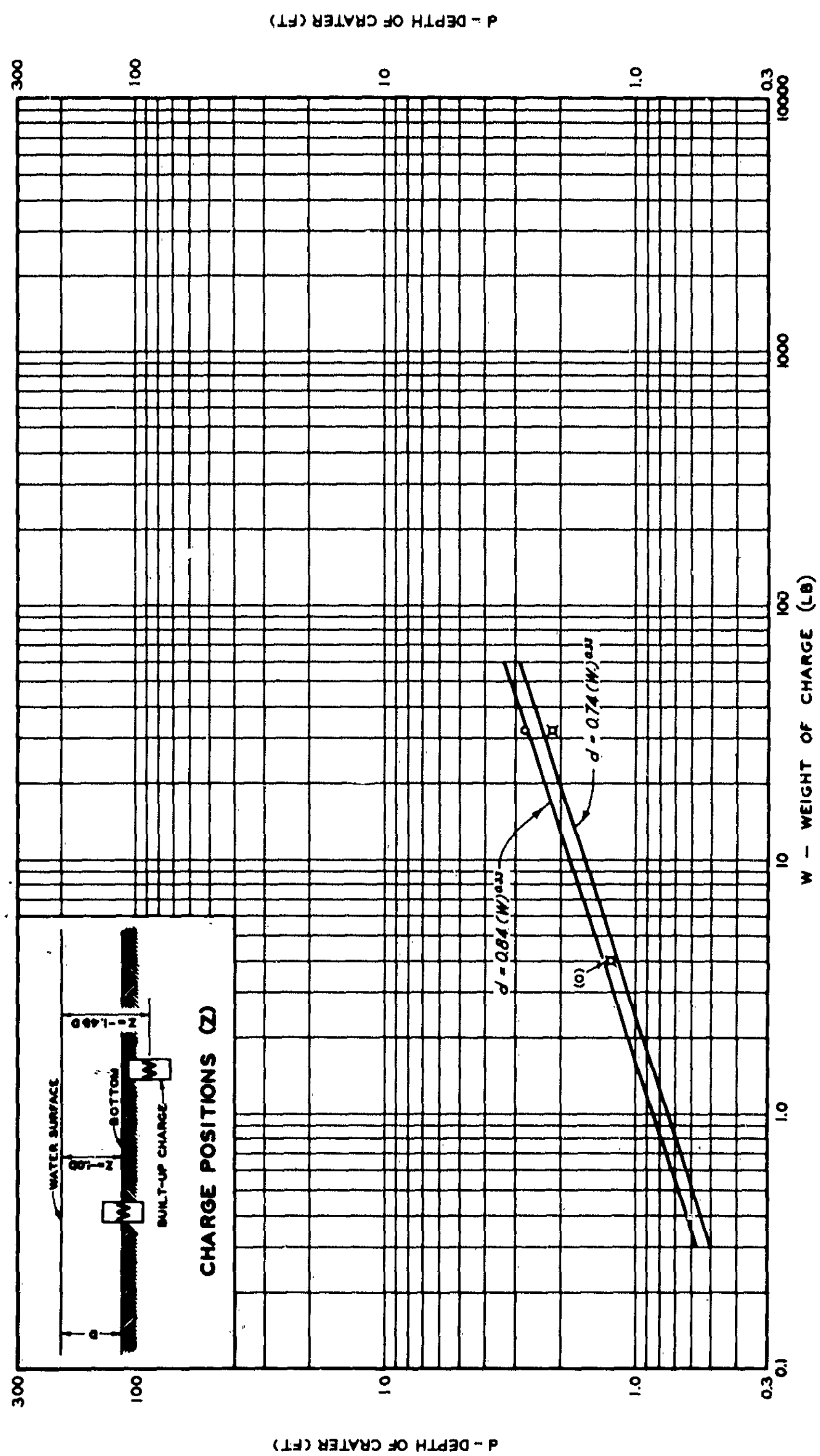

VARIATION OF CRATER DEPTH WITH CHARGE WEIGHT
DELTA POINT CLAY
$D/W^{\frac{1}{3}} = 0.585$
d - DEPTH OF CRATER (FT)
300
100
10
1.0
0.3
W - WEIGHT OF CHARGE (LB)
0.1
1.0
10
100
1000
10000
$d = 1.42\,(W)^{0.33}$
O CHARGE AT BOTTOM (Z = -1.0 D)
CHARGE POSITIONS (Z)
WATER SURFACE
BOTTOM
BUILT-UP CHARGE
W
Z=-1.0D
D

PLATE 53

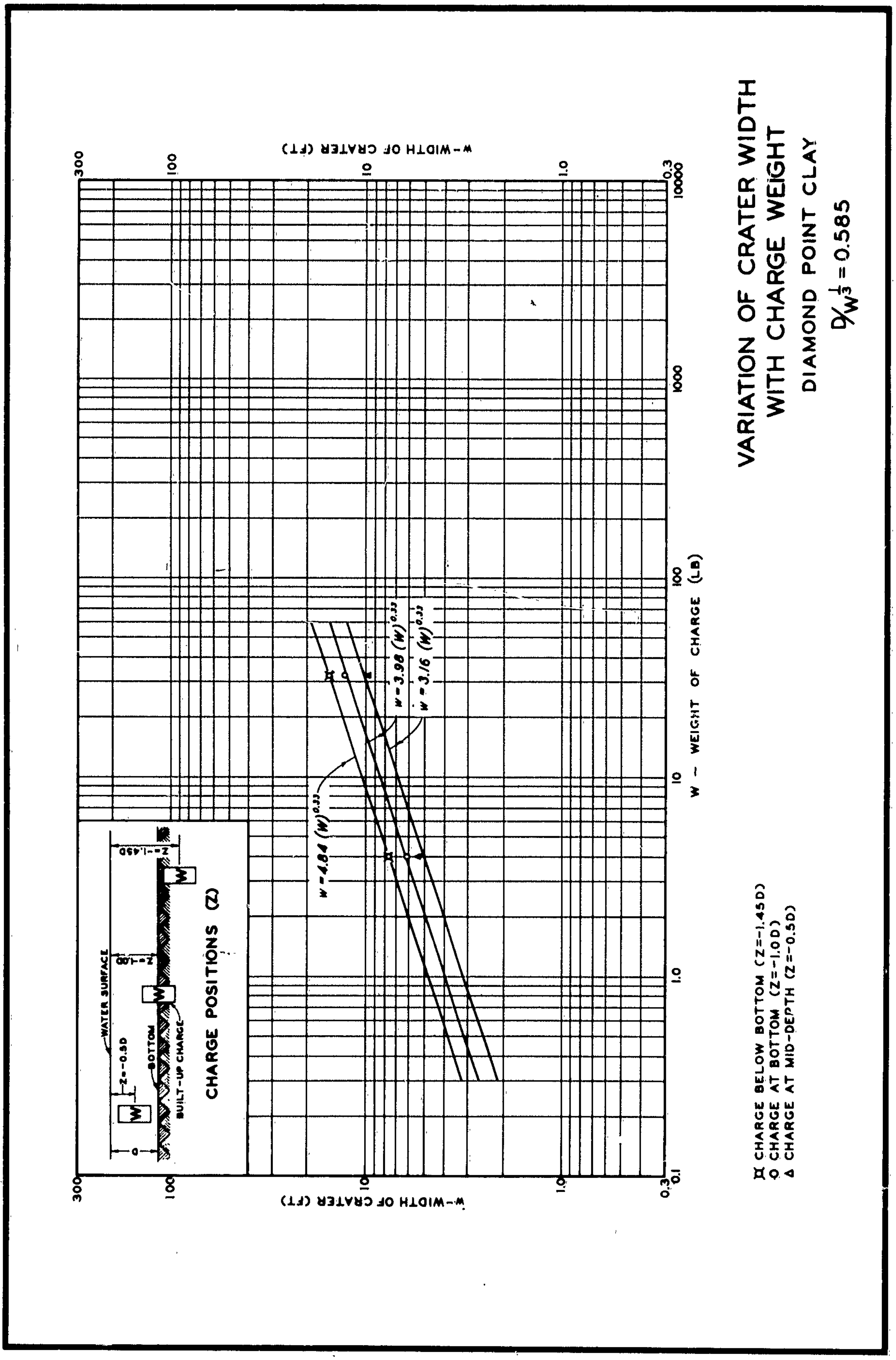


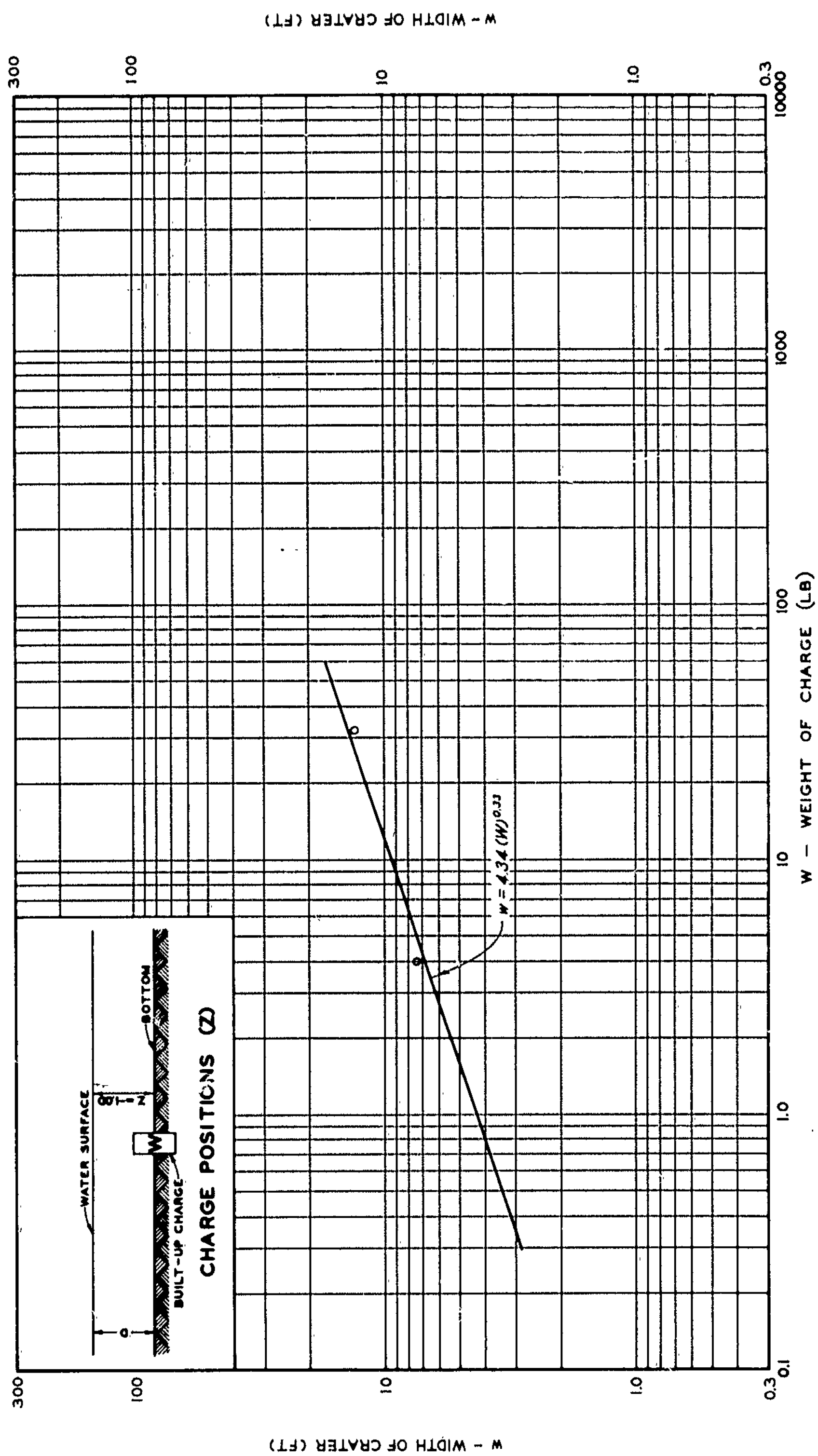

VARIATION OF CRATER DEPTH WITH CHARGE WEIGHT

SORRENTO CLAY

$D/W^{\frac{1}{3}} = 0.585$

¤ CHARGE BELOW BOTTOM (Z=-1.45D)
O CHARGE AT BOTTOM (Z=-1.0D)


VARIATION OF CRATER WIDTH
WITH CHARGE WEIGHT
DIAMOND POINT CLAY
$D/W^{\frac{1}{3}} = 0.585$
W - WEIGHT OF CHARGE (LB)
w-WIDTH OF CRATER (FT)
$w = 4.84\,(W)^{0.33}$
$w = 3.98\,(W)^{0.33}$
$w = 3.16\,(W)^{0.33}$
CHARGE POSITIONS (Z)
WATER SURFACE
BOTTOM
BUILT-UP CHARGE
Z=-0.5D
Z=-1.0D
Z=-1.45D
CHARGE BELOW BOTTOM (Z=-1.45D)
CHARGE AT BOTTOM (Z=-1.0D)
CHARGE AT MID-DEPTH (Z=-0.5D)

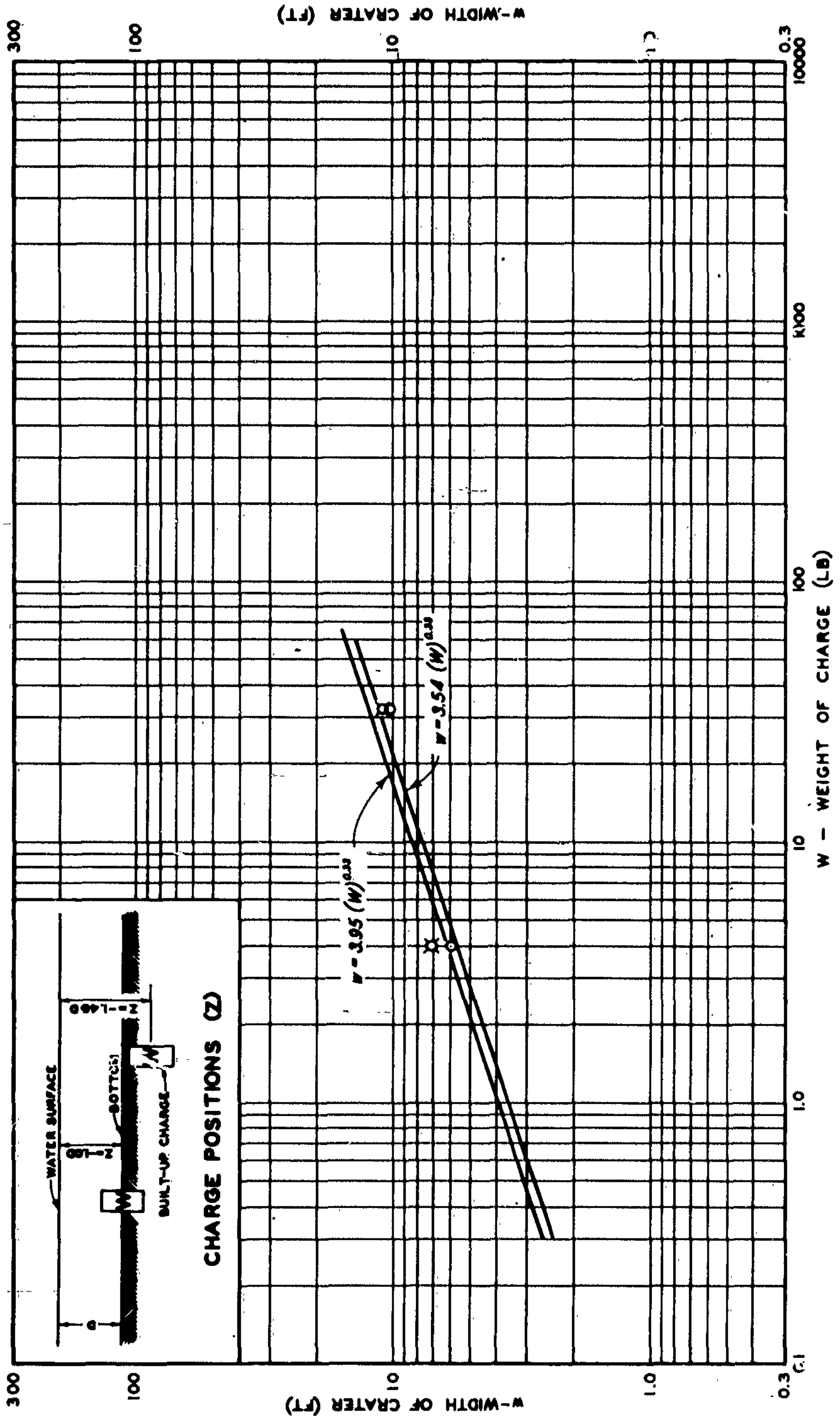



VARIATION OF CRATER WIDTH WITH CHARGE WEIGHT

DELTA POINT CLAY

$D/W^{\frac{1}{3}} = 0.585$

o CHARGE BELOW BOTTOM (Z = -1.0D)




VARIATION OF CRATER WIDTH
WITH CHARGE WEIGHT
SORRENTO CLAY
$D/W^{\frac{1}{3}} = 0.585$

☒ CHARGE BELOW BOTTOM (Z = -1.45 D)
○ CHARGE AT BOTTOM (Z = -1.0 D)

PLATE 57

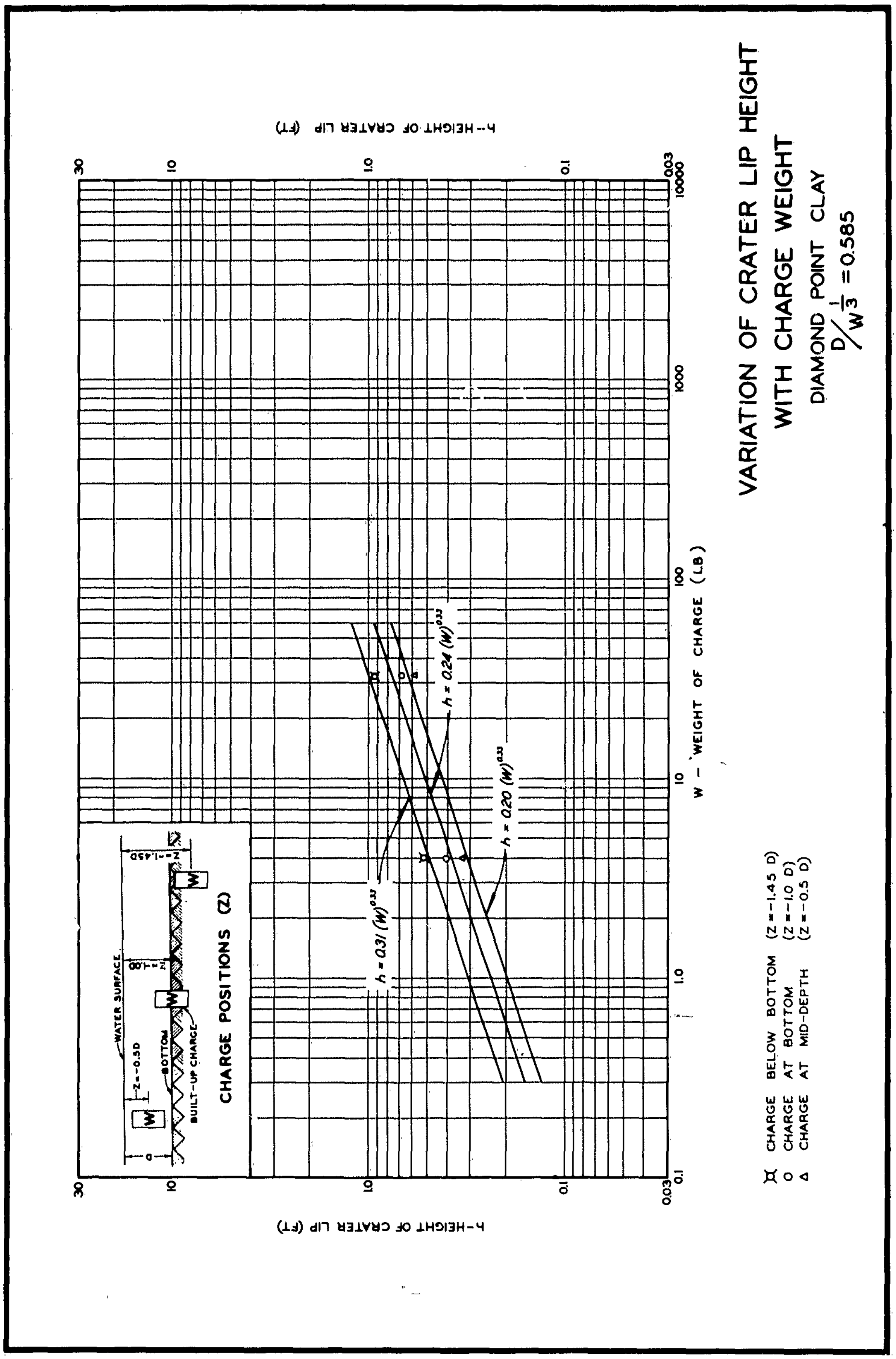
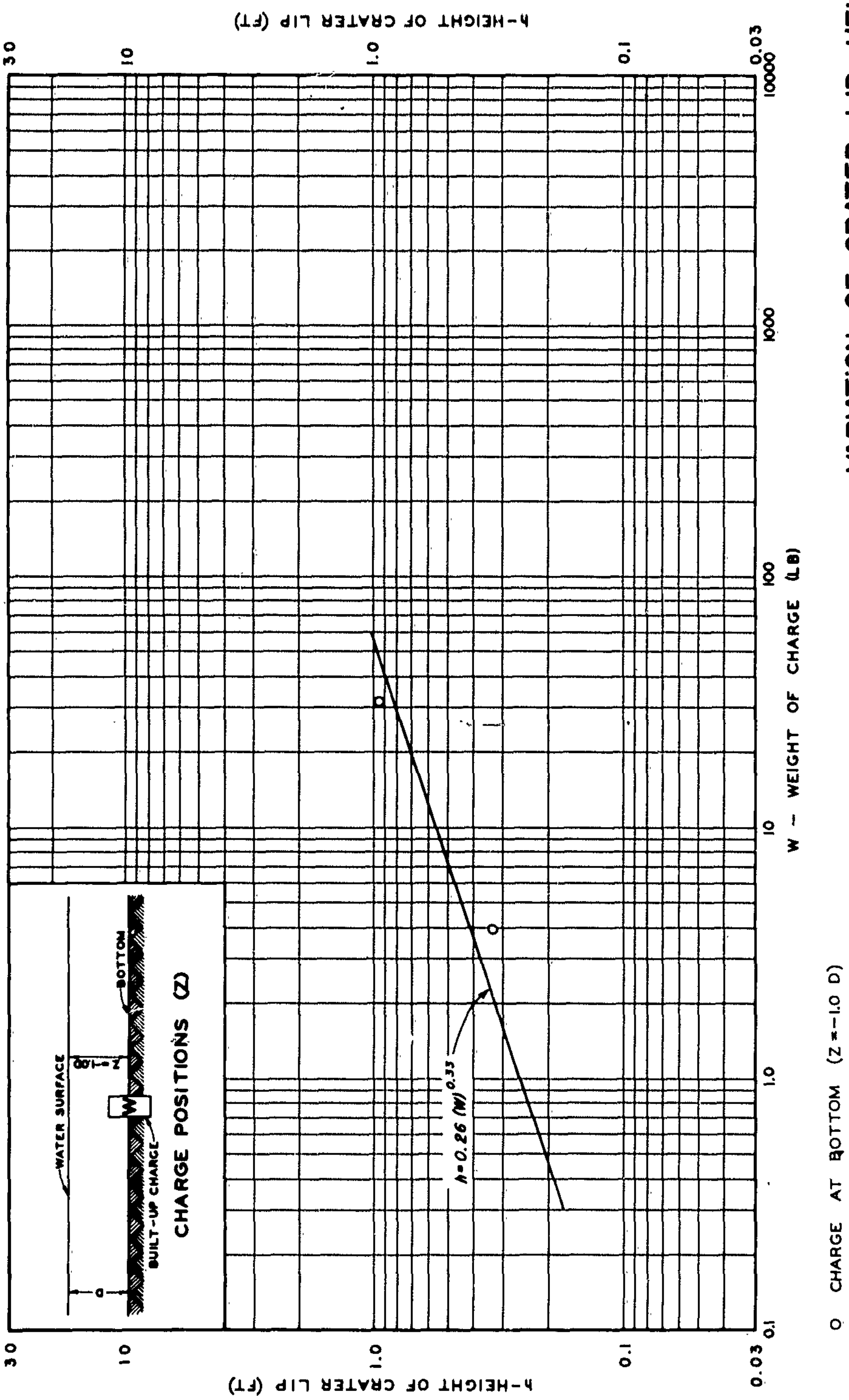
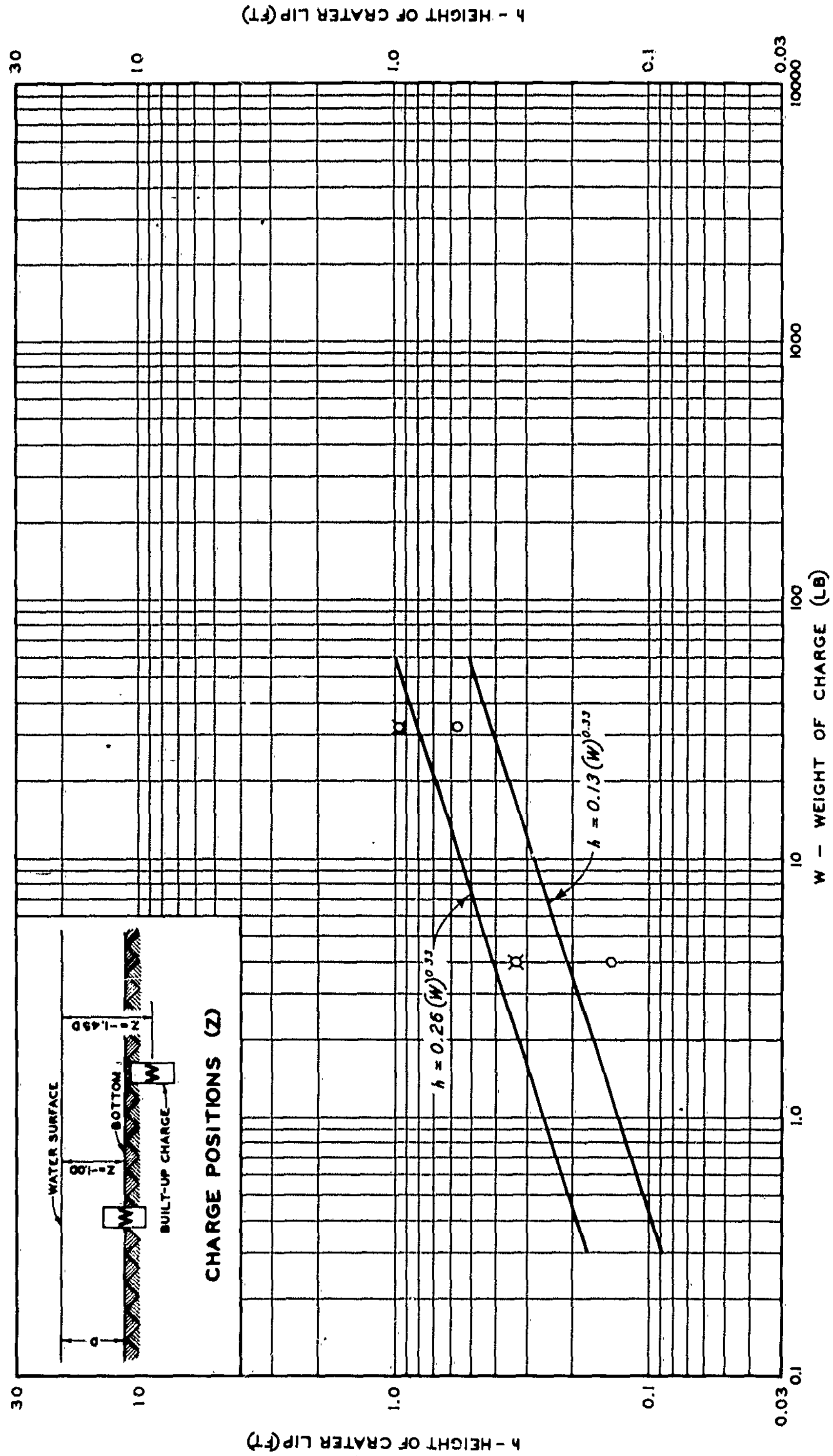

VARIATION OF CRATER LIP HEIGHT
WITH CHARGE WEIGHT
DIAMOND POINT CLAY
$D/W^{\frac{1}{3}} = 0.585$
h - HEIGHT OF CRATER LIP (FT)
W - WEIGHT OF CHARGE (LB)
$h = 0.31\,(W)^{0.33}$
$h = 0.24\,(W)^{0.33}$
$h = 0.20\,(W)^{0.33}$
CHARGE POSITIONS (Z)
WATER SURFACE
BOTTOM
BUILT-UP CHARGE
Z=-0.5D
Z=-1.0D
Z=-1.45D
D
W
¤ CHARGE BELOW BOTTOM (Z=-1.45 D)
○ CHARGE AT BOTTOM (Z=-1.0 D)
△ CHARGE AT MID-DEPTH (Z=-0.5 D)

PLATE 58




## VARIATION OF CRATER LIP HEIGHT WITH CHARGE WEIGHT
## DELTA POINT CLAY
$D/W^{\frac{1}{3}} = 0.585$

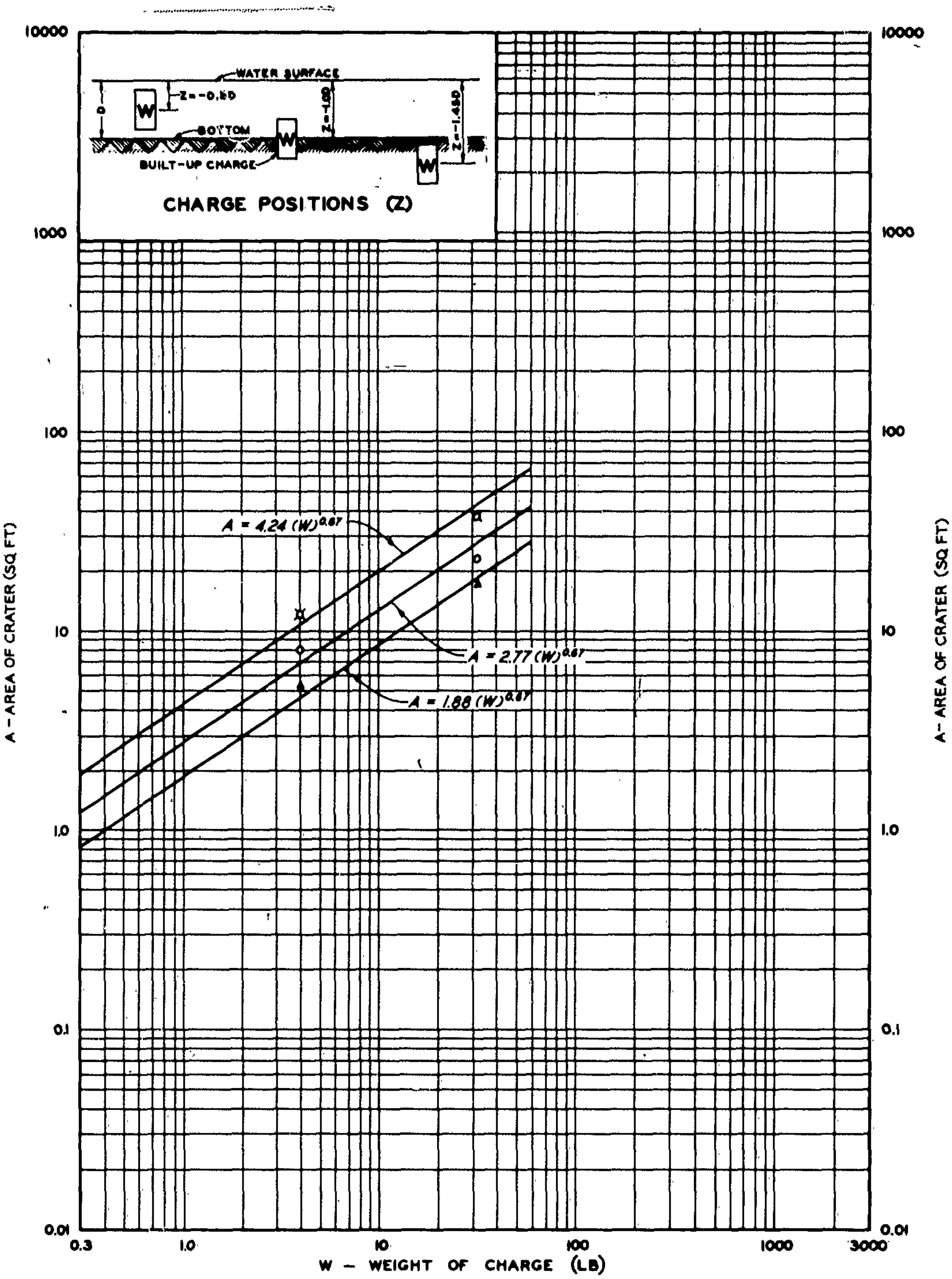



VARIATION OF CRATER LIP HEIGHT WITH CHARGE WEIGHT

SORRENTO CLAY

$D/W^{\frac{1}{3}} = 0.585$

¤ CHARGE BELOW BOTTOM (Z=-1.45D)
o CHARGE AT BOTTOM (Z=-1.0D)

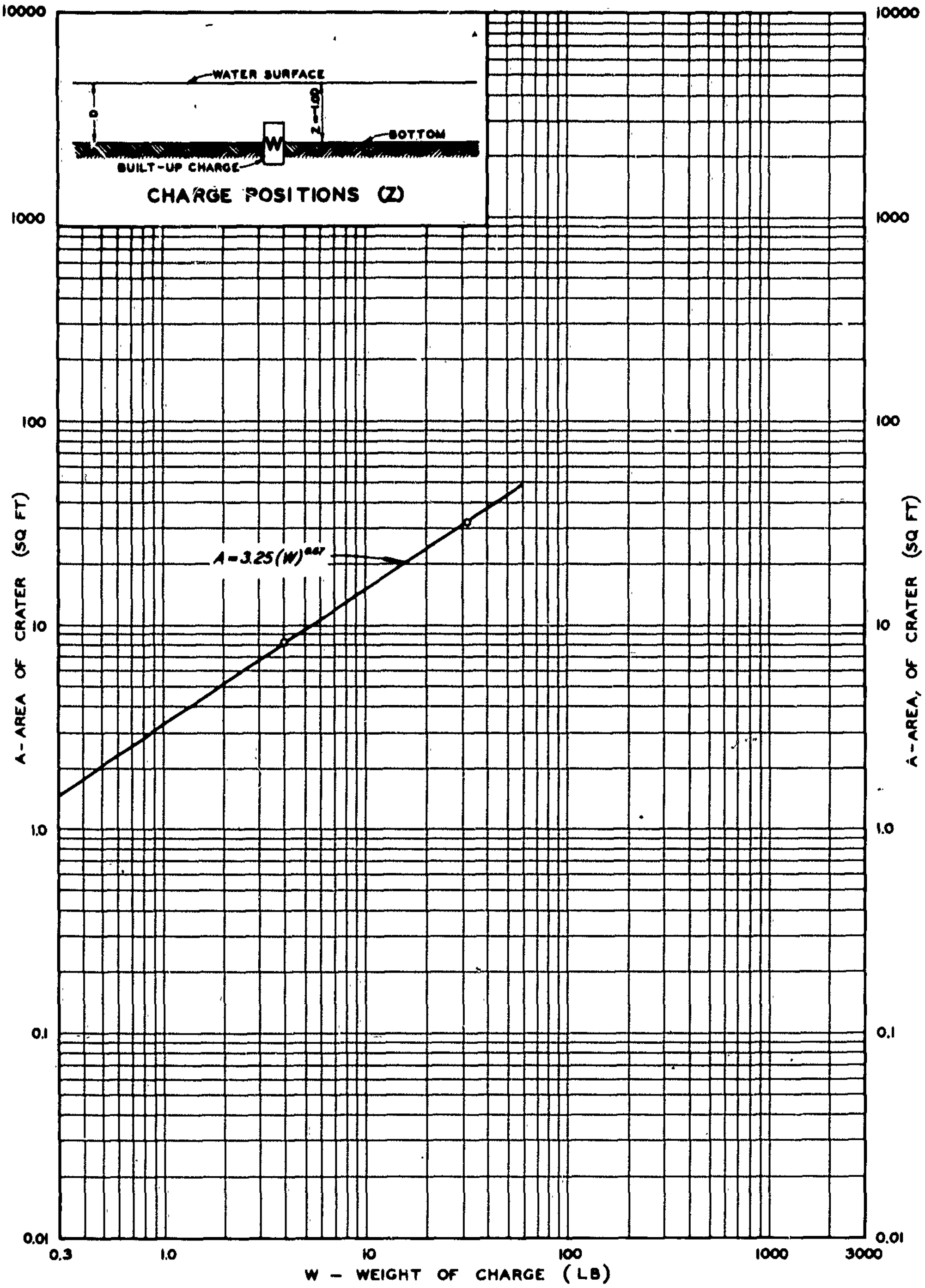



¤ CHARGE BELOW BOTTOM (Z = -1.45 D)
O CHARGE AT BOTTOM (Z = -1.0 D)
Δ CHARGE AT MID-DEPTH (Z = -0.5 D)

VARIATION OF CRATER AREA
WITH CHARGE WEIGHT
DIAMOND POINT CLAY
$D/W^{\frac{1}{3}} = 0.585$



CONFIDENTIAL
Security Information

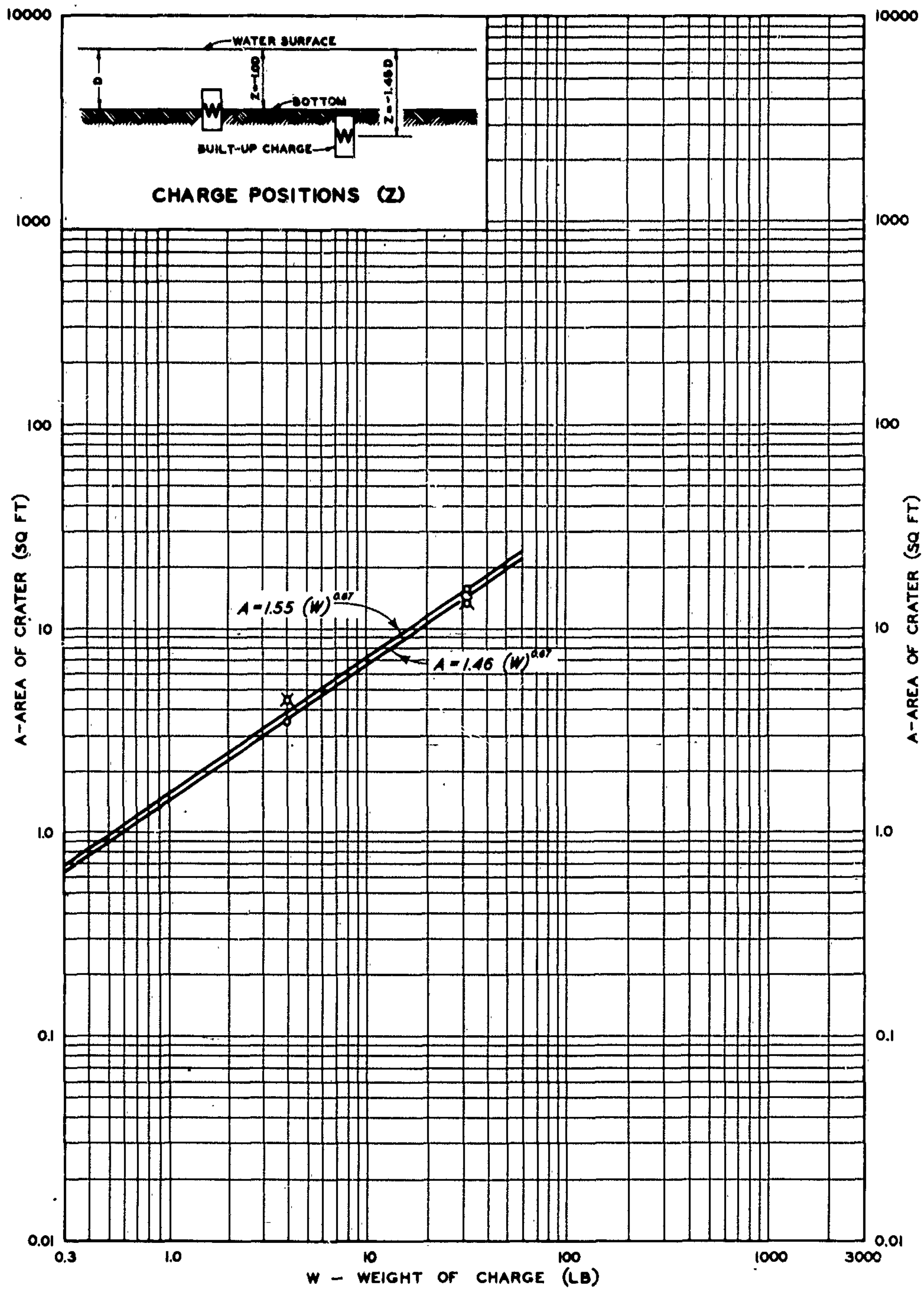



o CHARGE AT BOTTOM (Z = -1.0 D)

## VARIATION OF CRATER AREA WITH CHARGE WEIGHT

DELTA POINT CLAY

$D/W^{1/3}$ 0.585



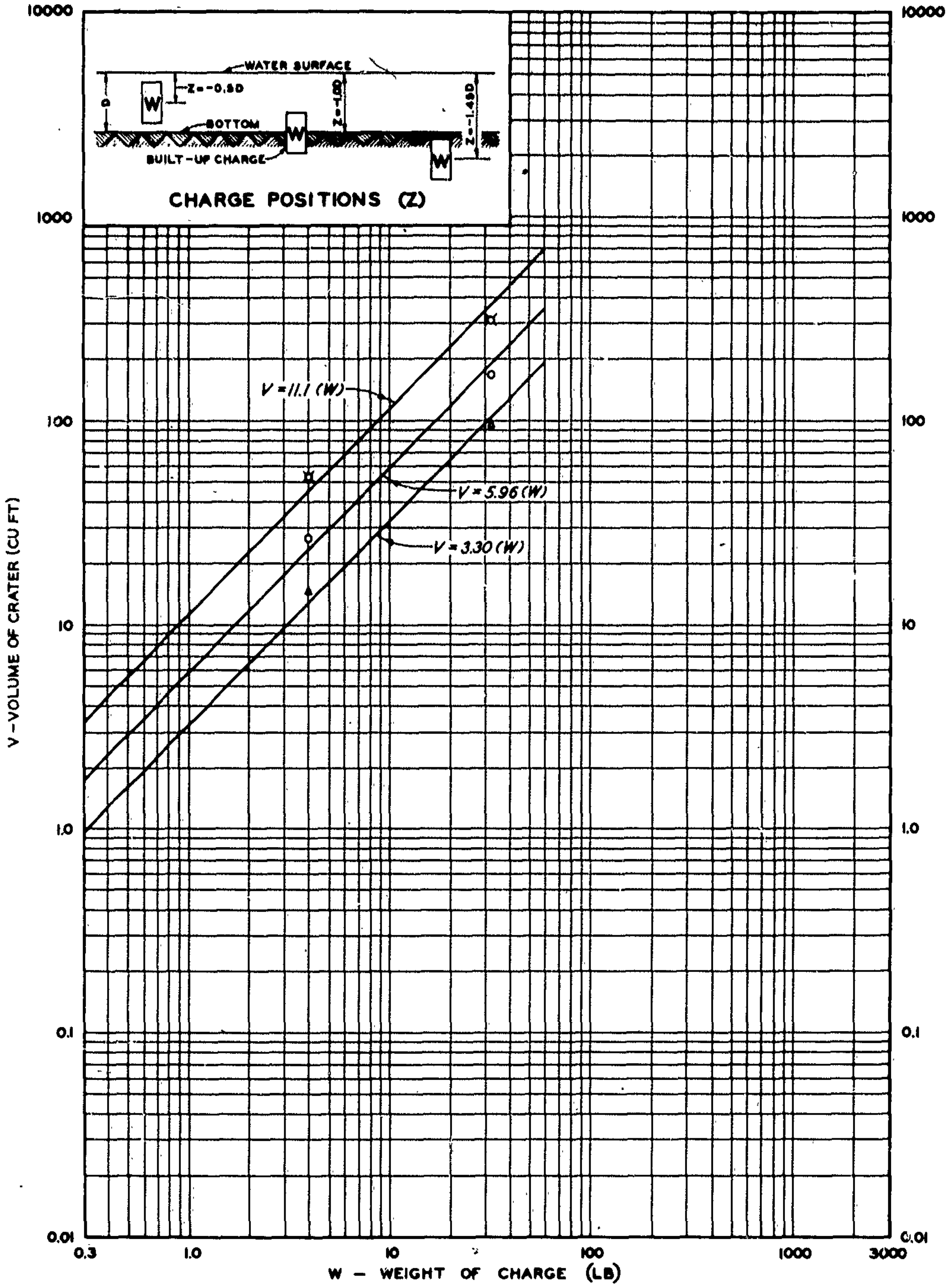

⌧ CHARGE BELOW BOTTOM (Z = -1.45 D)
O CHARGE AT BOTTOM (Z = -1.0 D)

**VARIATION OF CRATER AREA WITH CHARGE, WEIGHT**

**SORRENTO CLAY**

$D/W^{\frac{1}{3}} = 0.585$

PLATE 63



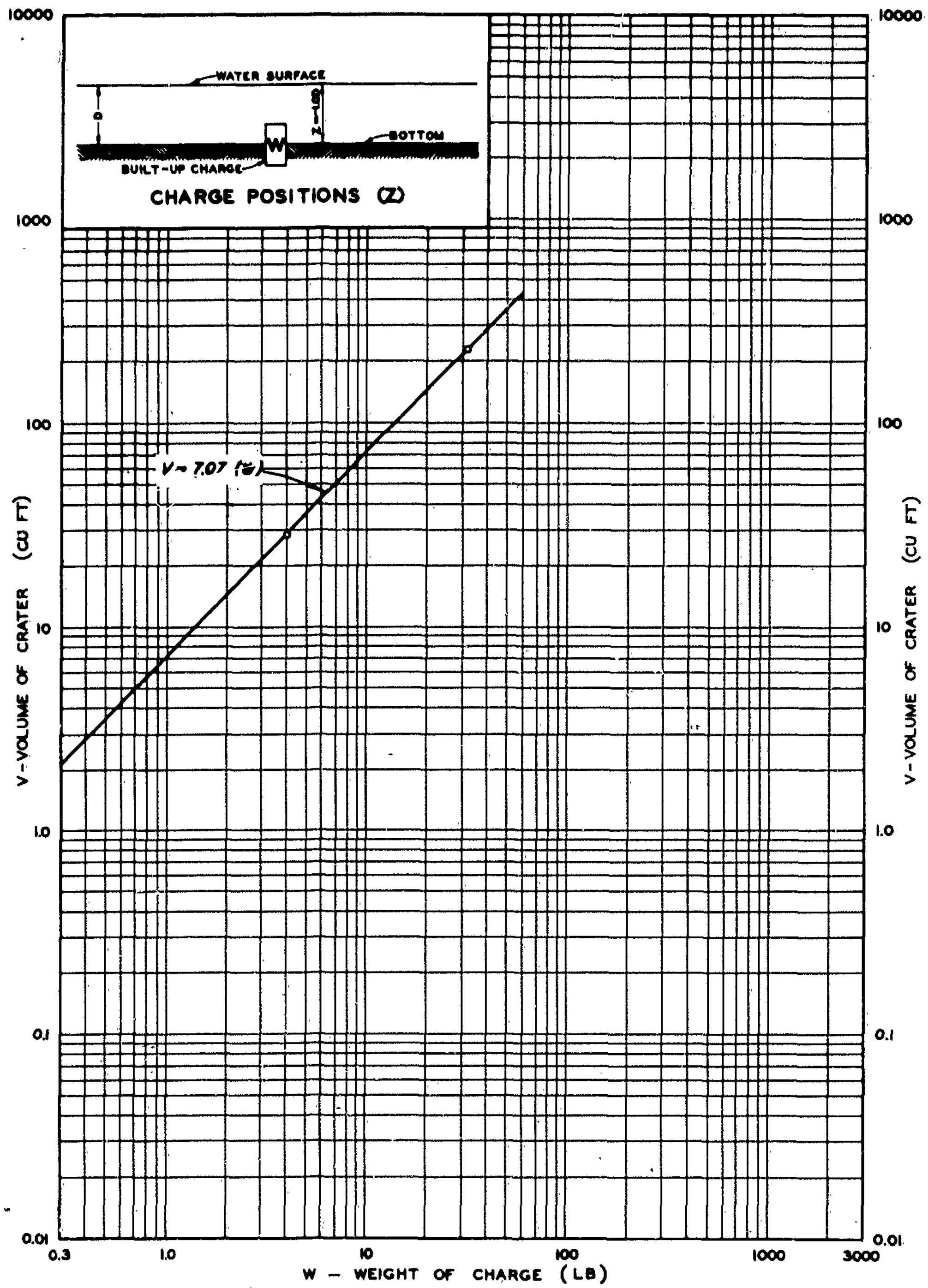

¤ CHARGE BELOW BOTTOM (Z=-1.45D)
○ CHARGE AT BOTTOM (Z=-1.0D)
△ CHARGE AT MID-DEPTH (Z=-0.5D)

VARIATION OF CRATER VOLUME
WITH CHARGE WEIGHT

DIAMOND POINT CLAY

$D/W^{\frac{1}{3}} = 0.585$

PLATE 64




O CHARGE AT BOTTOM (Z = -1.0 D)

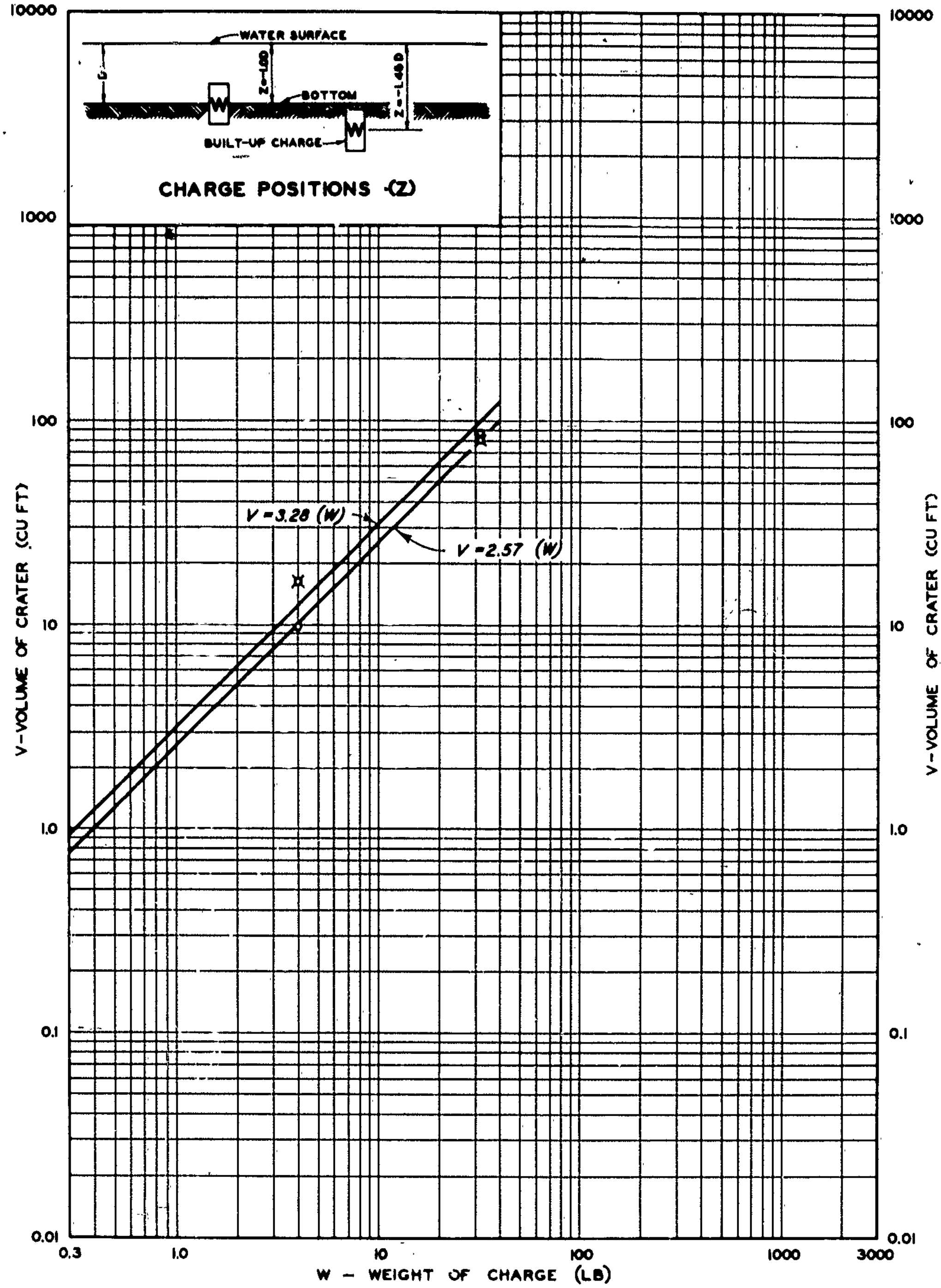
VARIATION OF CRATER VOLUME WITH CHARGE WEIGHT

DELTA POINT CLAY

$D/W^{\frac{1}{3}} = 0.585$



CONFIDENTIAL
Security Information

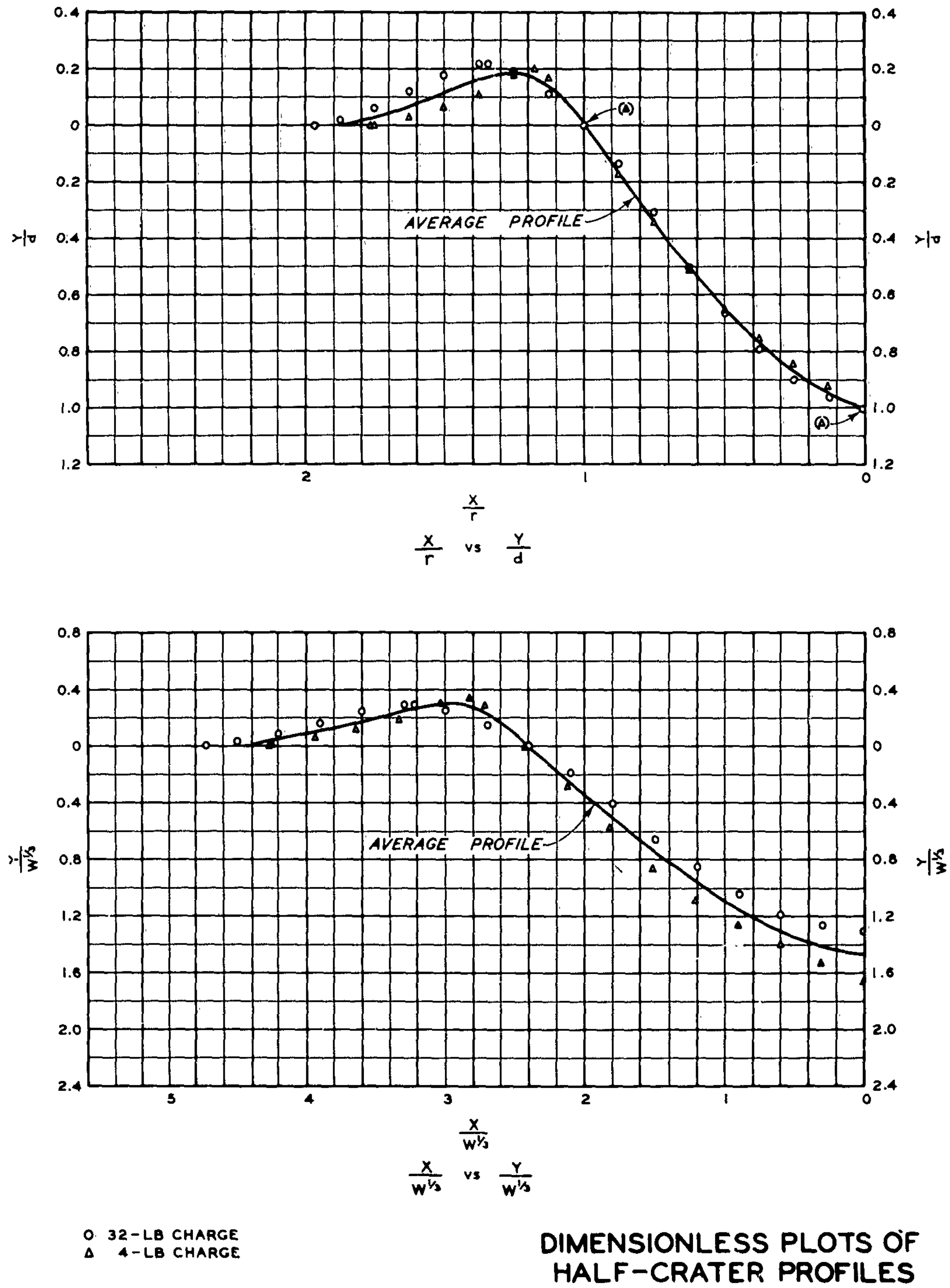



⌑ CHARGE BELOW BOTTOM (Z = – 1.45 D)
o CHARGE AT BOTTOM (Z = – 1.0 D)

## VARIATION OF CRATER VOLUME WITH CHARGE WEIGHT

SORRENTO CLAY

$D/W^{\frac{1}{3}} = 0.585$

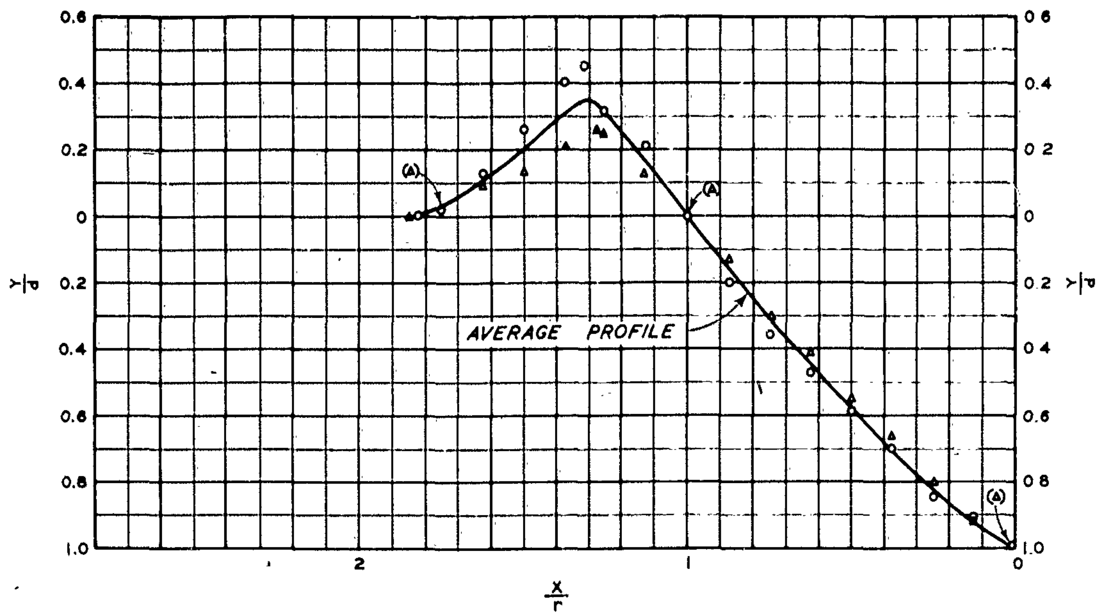



**DIMENSIONLESS PLOTS OF HALF-CRATER PROFILES**

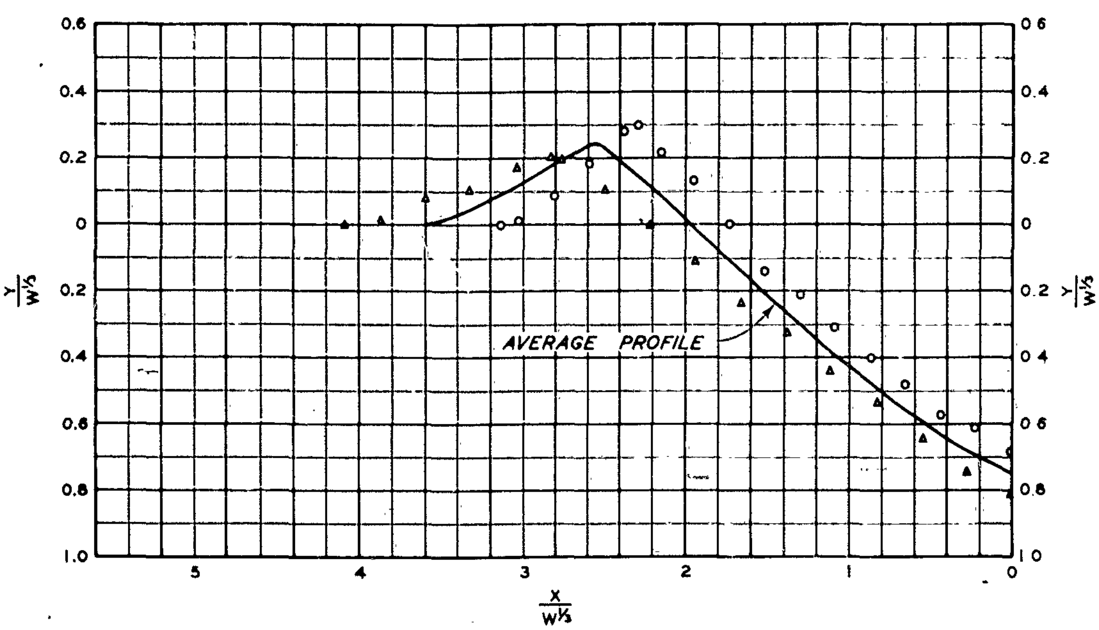
DIAMOND POINT CLAY

CHARGE BELOW BOTTOM ($Z=-1.45\,D$)

$D/W^{\frac{1}{3}} = 0.585$



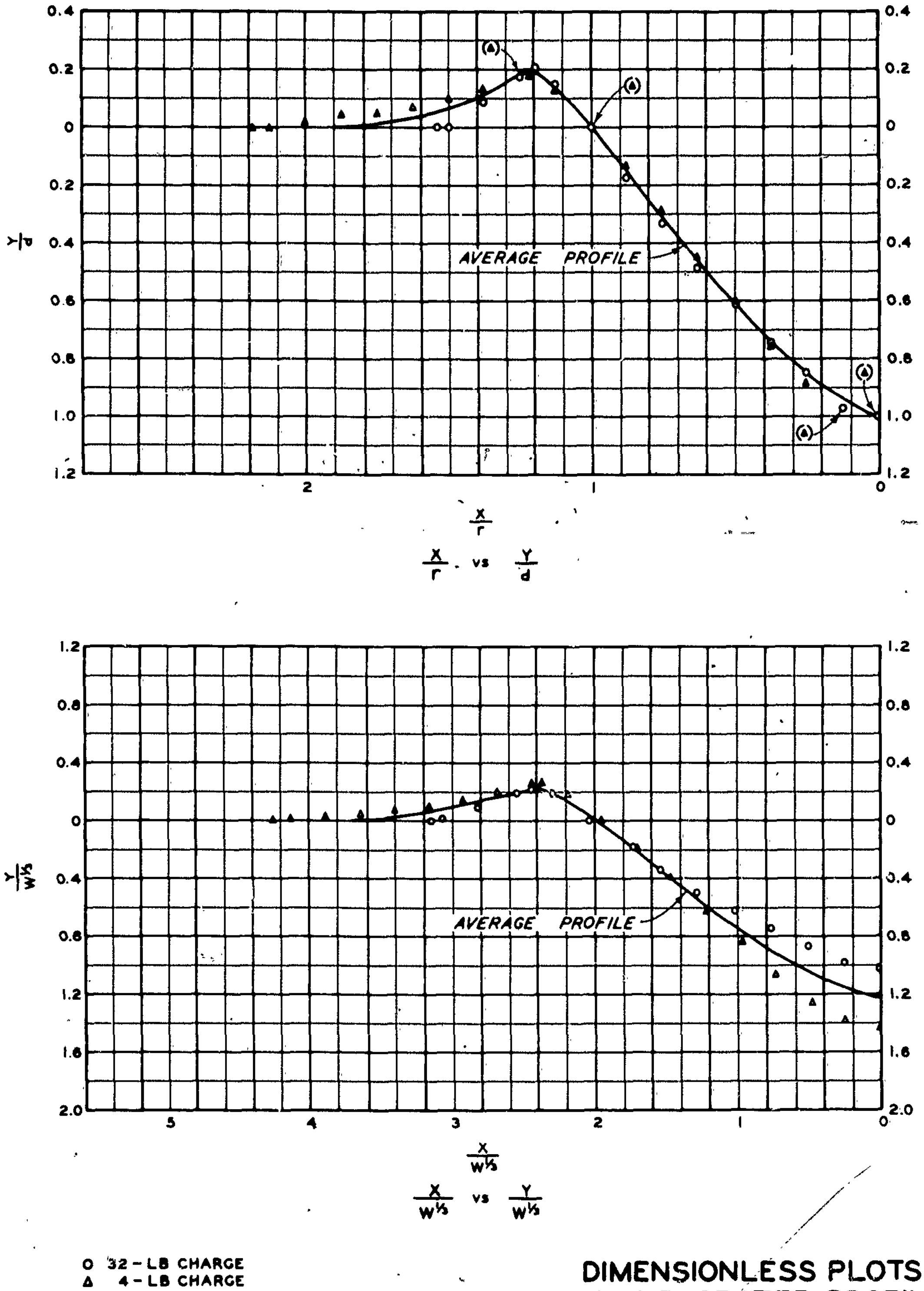

$\frac{X}{r}$ vs $\frac{Y}{d}$




$\frac{X}{W^{1/3}}$ vs $\frac{Y}{W^{1/3}}$

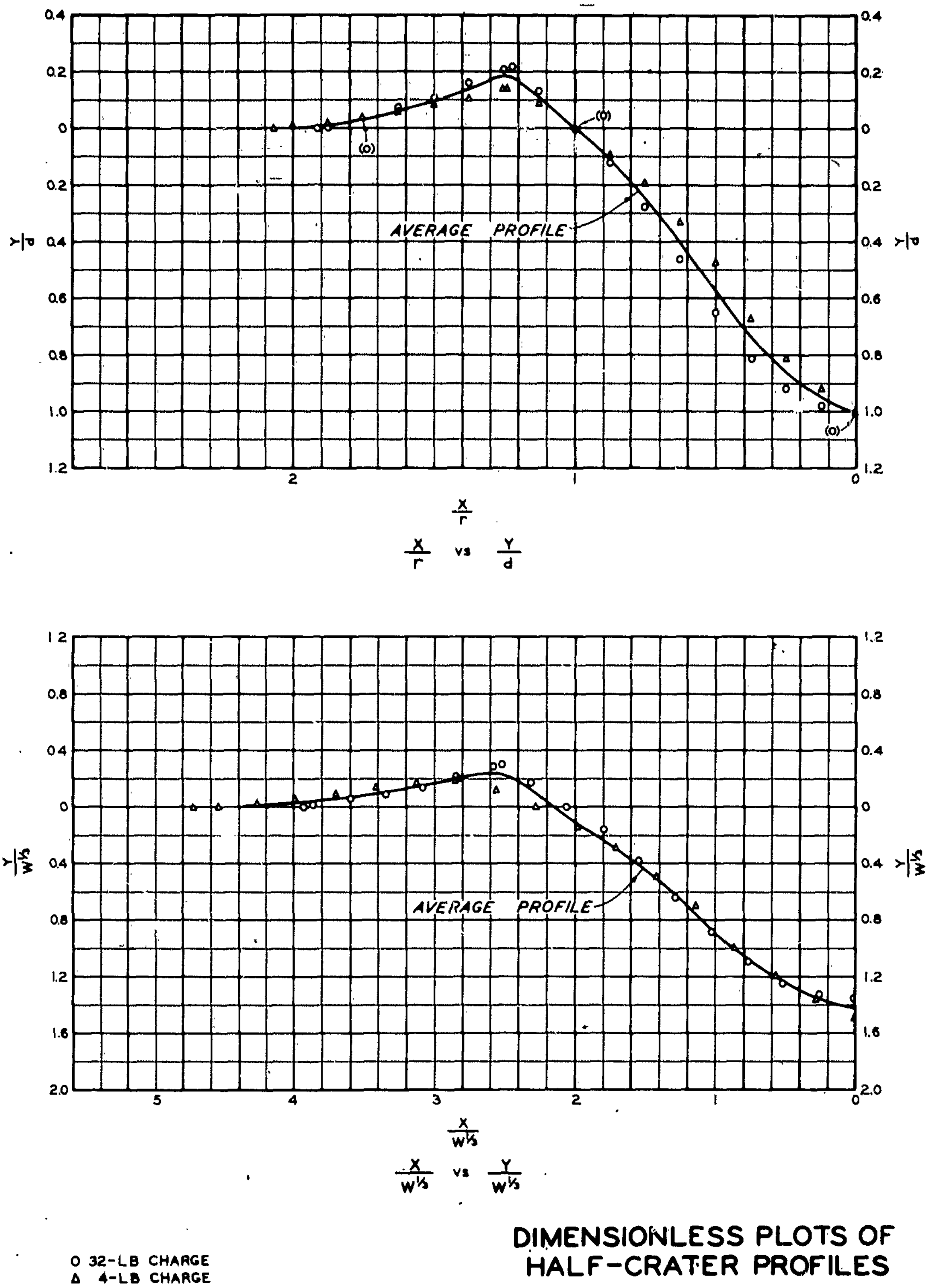
O 32-LB CHARGE
Δ 4-LB CHARGE

DIMENSIONLESS PLOTS OF
HALF-CRATER PROFILES
SORRENTO CLAY
CHARGE BELOW BOTTOM (Z=-1.45 D)
$D/W^{\frac{1}{3}} = 0.585$




DIMENSIONLESS PLOTS (
HALF-CRATER PROFILE
DIAMOND POINT CLAY
CHARGE AT BOTTOM (Z=-1.
$D/W^{\frac{1}{3}} = 0.585$

PLATE 69

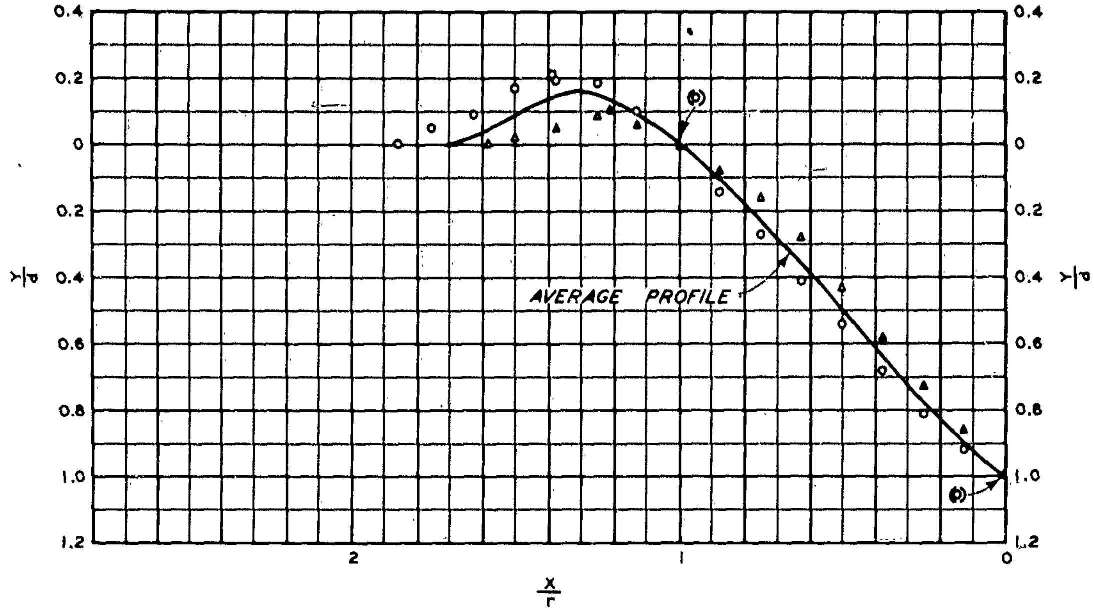



DIMENSIONLESS PLOTS OF HALF-CRATER PROFILES

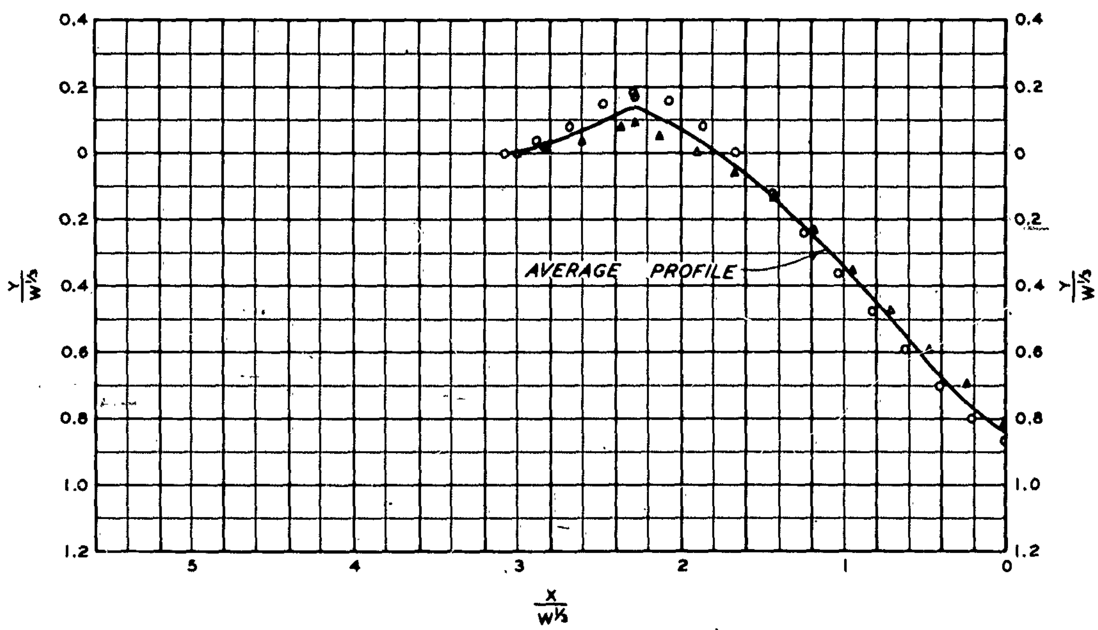
DELTA POINT CLAY

CHARGE AT BOTTOM (Z = −1.0 D)

$D/W^{\frac{1}{3}} = 0.585$



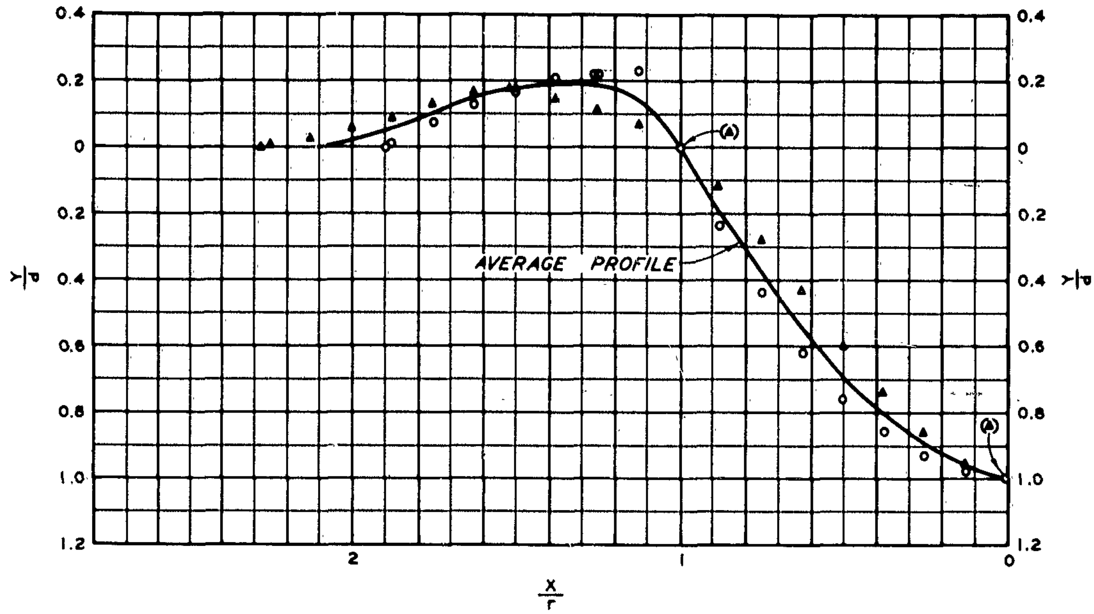

$\frac{X}{r}$ vs $\frac{Y}{d}$



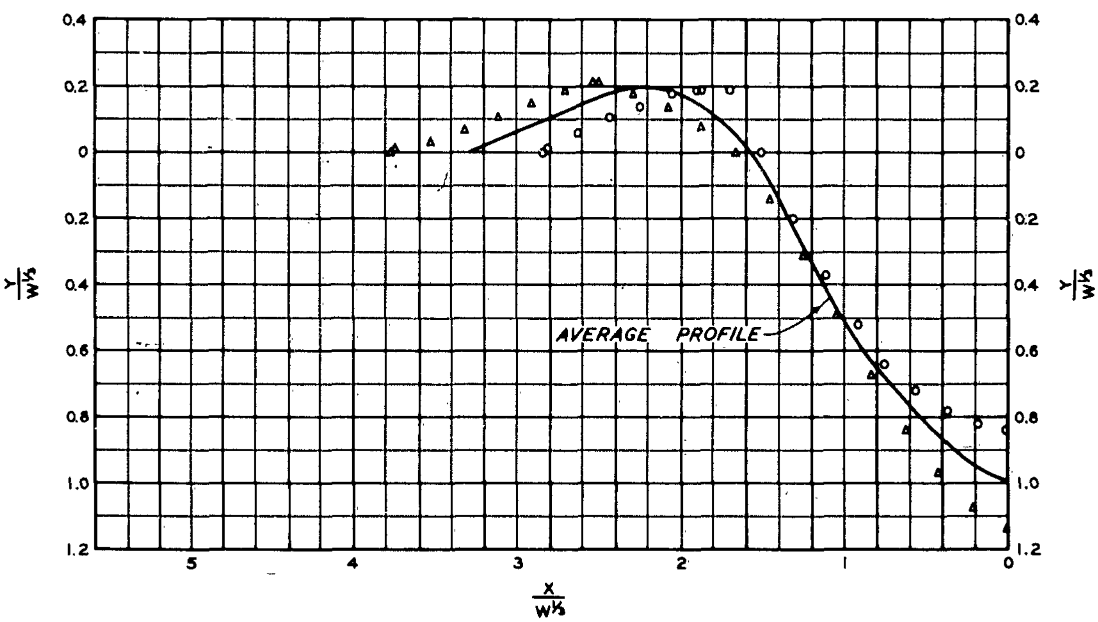

$\frac{X}{W^{1/3}}$ vs $\frac{Y}{W^{1/3}}$

O 32-LB CHARGE
Δ 4-LB CHARGE

DIMENSIONLESS PLOTS OF
HALF-CRATER PROFILES
SORRENTO CLAY
CHARGE AT BOTTOM (Z = −1.0D)
$D/W^{1/3} = 0.585$




X/r vs Y/d




$\frac{X}{W^{1/3}}$ vs $\frac{Y}{W^{1/3}}$

O 32-LB CHARGE
Δ 4-LB CHARGE

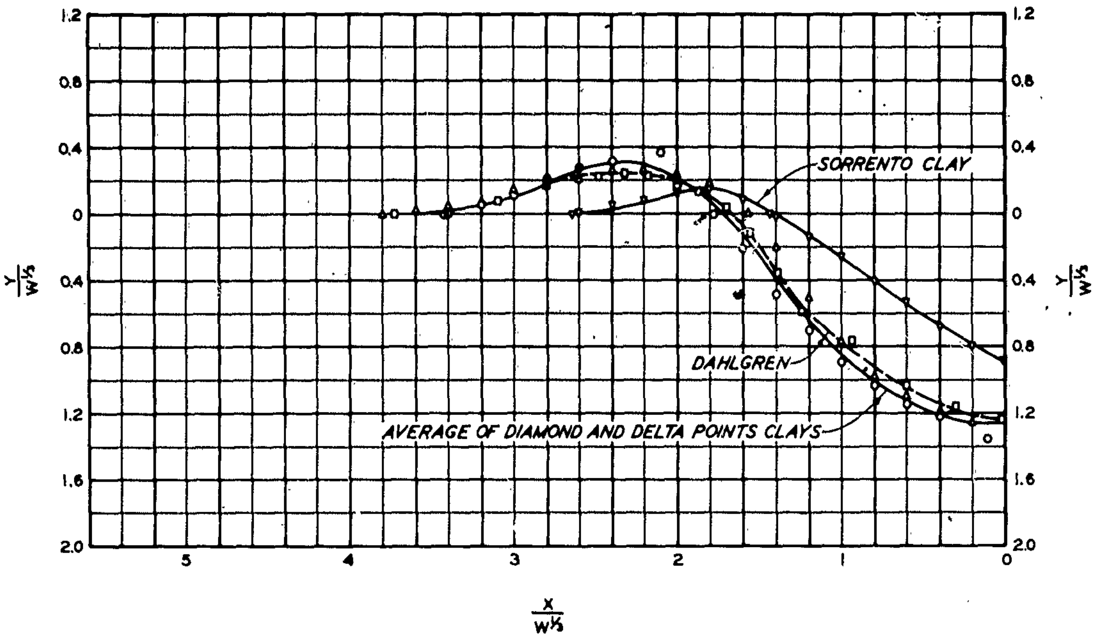
**DIMENSIONLESS PLOTS OF HALF-CRATER PROFILES**

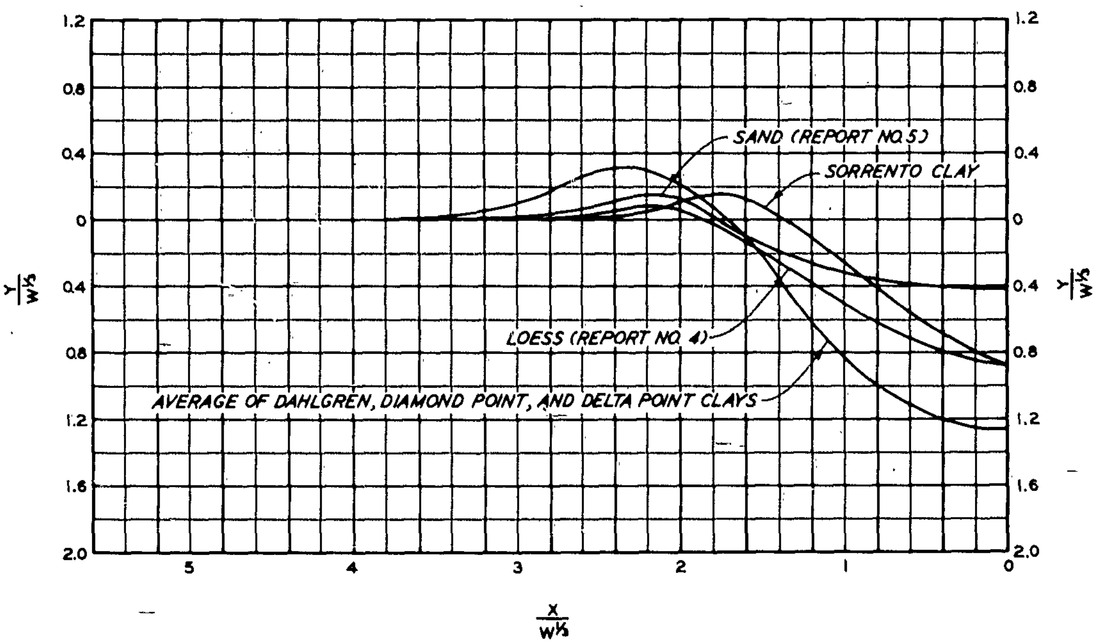
DIAMOND POINT CLAY

CHARGE AT MID-DEPTH (Z=-0.5 D)

$D/W^{\frac{1}{3}} = 0.585$

# PLATES 73 AND 74
## SUMMARY



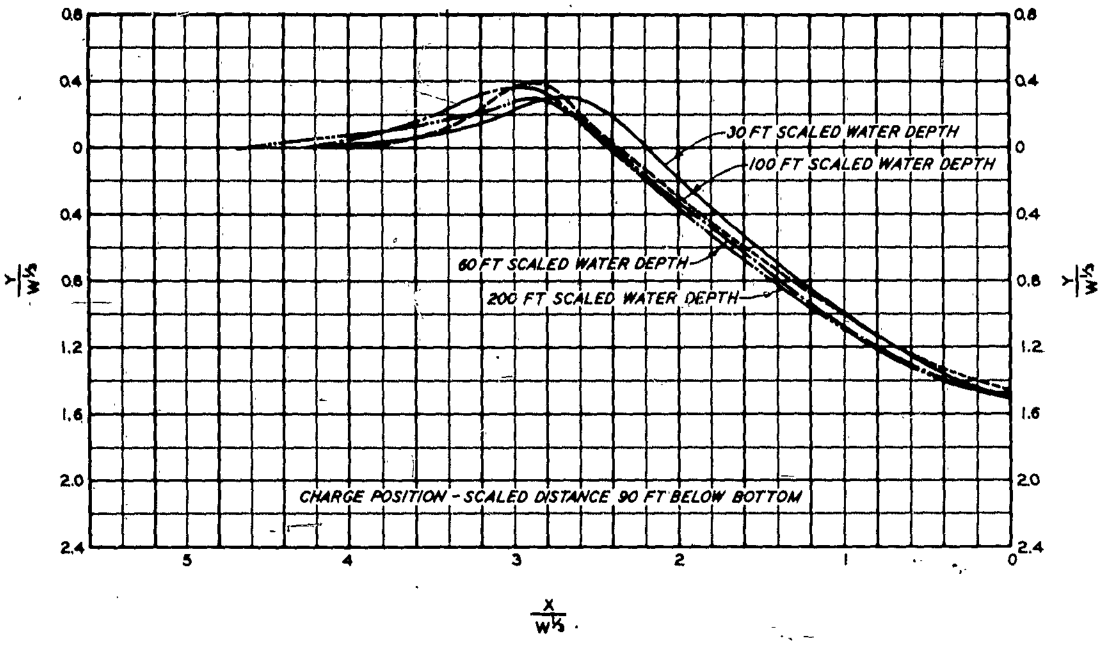



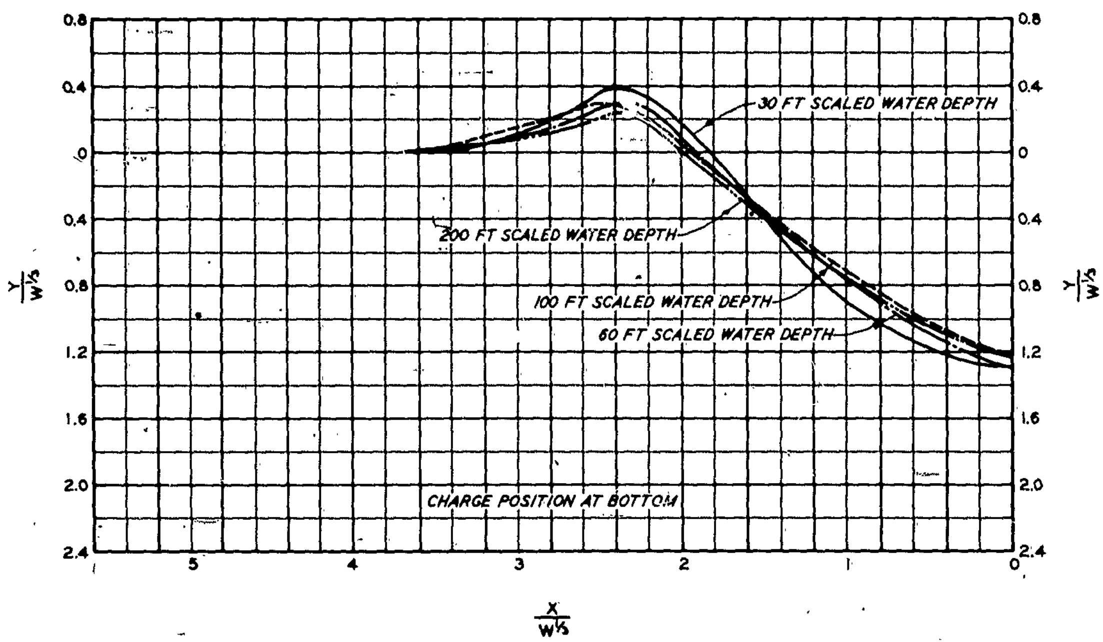

O DIAMOND POINT
Δ DELTA POINT
∇ SORRENTO
□ DAHLGREN

DIMENSIONLESS PLOTS OF HALF-CRATER PROFILES

CHARGE AT BOTTOM (Z = −1.0 D)

$D/W^{\frac{1}{3}} = 0.088$




## DIMENSIONLESS PLOTS OF HALF-CRATER PROFILES

DIAMOND POINT CLAY
CHARGE POSITIONS AS SHOWN